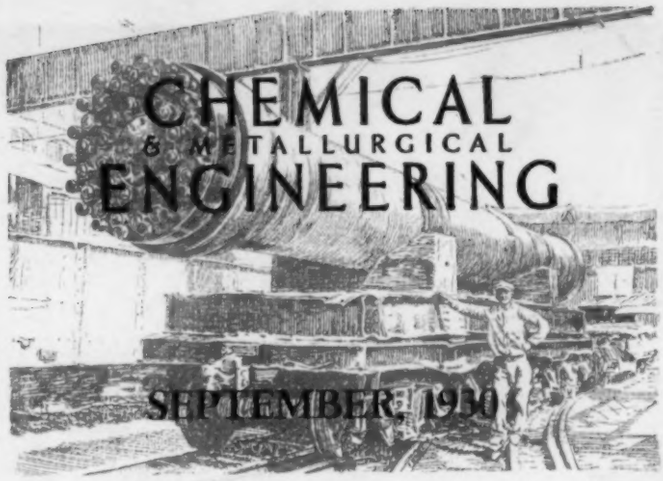

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VOLUME 37

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NUMBER 9

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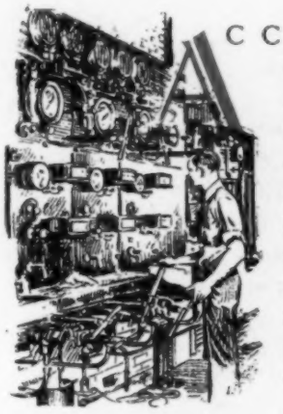
S. D. KIRKPATRICK, *Editor*

September, 1930

Pressure and Temperature Applied to Industrial Progress

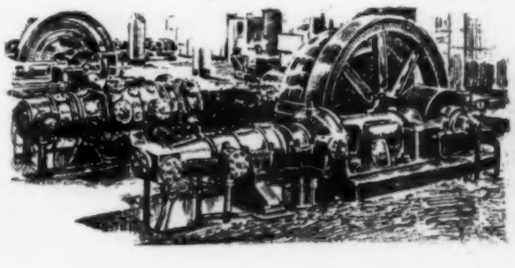


ACCELERATED change has come to be a dominant characteristic of our present-day civilization. As never before in history, industry has undergone a practically continuous technical revolution of methods and materials, processes, and products. Chemical change, often sluggish by nature, has been the responsible incentive to much of the progress that has taken place.

To accelerate chemical reactions in the laboratory, the two great available agencies are pressure and temperature. But to direct and control these effectively on a profitable, industrial scale has called for an entirely new technology—one with which the chemical engineer is intimately concerned. High pressures and temperatures have been made useful tools of industry largely through the solution of practical problems of engineering materials and the design and construction of equipment. Although obviously only on the threshold of its ultimate development, the new technology has become the miracle worker of chemical industry.

In less than ten years, nitrogen fixation has grown to be one of the largest heavy-chemical enterprises. Hydrogenation, methanol, and other syntheses have revolutionized established businesses. Older industries that have not yet felt the full effect of the new technology are threatened. Tremendous expansion is certain to follow in the trend that is now plainly indicated.

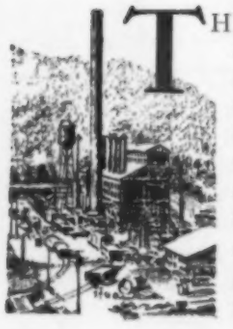
Close association, in point of time, with any revolutionary advance in industry is likely to produce either disproportionate praise or inadequate appreciation. In this issue *Chem. & Met.* attempts to steer between the Scylla and Charybdis of these extremes. It places before its readers a summary and correlation of what has been accomplished and, on this basis, points the way to further progress. If it brings home to the chemical engineer, in whatever industry he may be, the extraordinary chemical achievements, the engineering advances that have made them possible, and the far-reaching economic changes that have resulted from the application of the new technology, this issue will have accomplished but part of its purpose. In addition, it is earnestly hoped that it may stimulate the chemical engineer to make even greater use of high pressures and temperatures in accelerating the normal processes of industrial progress.



High-Pressure High-Temperature T

The Chemical Engineer's Newest and Most Effective Tool

INDUSTRIAL DEVELOPMENTS involving high pressures and temperatures are among the most remarkable achievements of chemical engineering in modern times. To interpret these developments in their present significance and future potentialities, *Chem. & Met.* has secured, as consulting editor for this issue, the services of Prof. Norman W. Krase, of the chemical engineering division of the University of Illinois. The present article and several of those that follow it reflect, therefore, in addition to the editorial viewpoint, the experience of one who has been intimately connected with the early growth and recent progress of this new technology.—*Editor.*



THE PRESENT EFFORT of *Chem. & Met.* to evaluate and interpret the new high-pressure, high temperature technology is timely, for many infant developments of before the war have now grown to full stature and at present constitute some of the largest and most active of our chemical processes. In addition, sufficient progress has been made so that the necessary engineering service, technique, equipment, and trained personnel are available for extending the application of pressure to new fields. When it is realized that approximately $100,000,000 is invested in strictly pressure plants and that the annual value of their product approaches $50,000,000, it will be seen that no longer are we dealing with an experimental project but that we must give place and recognition to an established business.

What are the specific accomplishments of "high pressures" that merit this attention? The synthetic ammonia industry, based on such prosaic materials as coke, air, and water, and producing therefrom the valuable heavy chemical, ammonia, stands first in commercial importance. The existence of this industry within the boundaries of the United States makes this country entirely independent in the matter of nitrates for national defenses and in the supply of nitrogen compounds for manifold peace-time uses. It has cut the cost of anhydrous ammonia in cylinders from 30 cents per pound to 15 cents a pound in less than ten years and it may now be purchased in tank cars for less than 6 cents a pound. This development has made available as a raw material for the chemical industry a very valuable and versatile product.

Anhydrous synthetic ammonia, because of its purity, has captured the refrigeration market. Its use in ammoniating acid phosphate is growing. Large tonnages are oxidized to nitric acid and marketed as such or as synthetic sodium nitrate. If present developments are given a reasonable extrapolation we find in them much promise for the farmer in the matter of cheap nitrogenous fertilizer. Miscellaneous uses for synthetic ammonia are numerous and on the increase. Even at present prices it can be sold as a substitute for compressed hydrogen in small cylinders, to be "cracked" into its elements and the hydrogen burned. It is significant that five years ago less than 30 per cent of all fixed nitrogen produced was by way of ammonia synthesis; today about 50 per cent is so made, and the total world production has doubled during that period.

Synthetic methanol, a more recent offspring of its high-pressure antecedents, has grown from no production in 1920 to an output in 1929 of almost five million gallons. What this has meant to many users of solvents and synthetic resins has been told many times in recent

Technology

By NORMAN W. KRASE

Chemical Engineering Division
University of Illinois, Urbana
Consulting Editor, Chem. & Met.

Like many others who now play prominent parts in the pressure industries, Dr. Norman W. Krase received his first schooling in the new technology at the Fixed Nitrogen Research Laboratory. This began in 1919 after Lieutenant Krase had resigned his commission in the Chemical Warfare Service. It ended in 1923 when he left the government's service to serve as instructor in chemical engineering at Yale University and to complete a doctorate thesis on improvements in nitric-acid manufacture. Since 1926 Dr. Krase has been associate professor of chemical engineering at Illinois, in charge of high pressure work, conducting a program of cooperative research on fundamental measurements and new industrial processes

chemical literature. In addition to creating considerable nervousness in the wood-distillation industry, which formerly supplied the bulk of this compound, the large-scale production of methanol has made available to the chemical industry a raw material of great usefulness at a low price—some 40c. per gallon, compared with 90c. but a few years ago. These economic trends are clearly shown by the accompanying graphs based on data presented before the Manufacturing Chemists' Association by Jasper E. Crane, of the duPont company. Present production of synthetic methanol is confined to such installations having either byproduct hydrogen or carbon monoxide available from other operations. The synthetic product goes largely into formaldehyde and resin manufacture, into solvents, denaturants and, more recently, into anti-freeze solutions.

HYDROGENATION of petroleum, forecast by the early experiments of Bergius on the hydrogenation of coal, is in a fair way to reach commercial significance in the United States this year. Preliminary announcements describe a process which is capable of converting even the crudest of crude oils into gasoline of excellent quality. In addition to gasoline, many other valuable compounds may be formed from petroleum as a starting material. The flexibility of the hydrogenation process permits refineries to adjust their output in accordance with the demands of the consuming market, producing gasoline, kerosene, gas oils, or lubricants in the proportion desired. The process permits 100 per cent conversion of crude oil into marketable gasoline, as compared with about 70 per cent by the cracking operations now used. It eliminates many waste products; for example, sulphur, the bugaboo of the oil refiner, passes out of the picture as hydrogen sulphide, leaving low-sulphur products even from high-sulphur crudes. The present policy contemplates making these developments available to oil companies generally through leasing of patents. To call such a development revolutionary is to be extremely conservative.

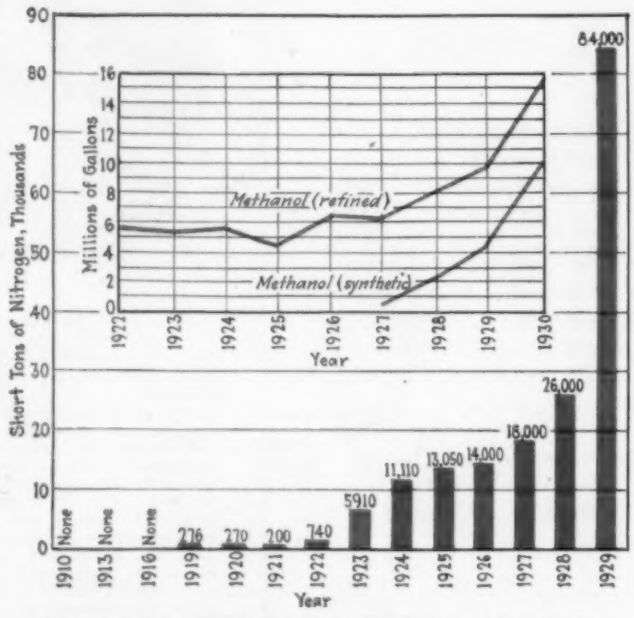
Plants are practically ready to go into operation to produce higher alcohols from carbon monoxide and hydrogen by pressure-catalytic processes. Isobutyl alcohol probably will be the first of these to reach commercial production. There is no valid reason known to research workers in this field why many other compounds of great value to the industry cannot be produced from similar starting materials by similar methods. As is to be expected when so many compounds are theoretically possible by reactions of carbon monoxide and hydrogen, a great variety of products are formed by pressure-catalytic methods. The outstanding problem in this field is the development of catalysts and conditions that will yield practically pure, single compounds or, at least, simple mixtures. That this will be done is a foregone conclusion and awaits only time and patience on the part of research workers. As these possibilities are gradually developed and knowledge accumulates we may expect a remarkable stimulation of the work in the field of synthetic organic chemistry by extended application of pressure methods.

It is interesting to note some of the miscellaneous applications of high-pressure technique to chemical engineering problems. When the world was first informed of Fischer's work on the production of "Synthol" from water gas, much enthusiasm was created and many predictions were ventured. Later developments have justified the confidence placed in this process, which, in cer-

tain localities, holds much for the future in the way of producing automotive fuel. The problem of producing complex mixtures of partly oxygenated hydrocarbons is a much simpler one than that of forming simple mixtures and accordingly should develop more rapidly.

The methanation of carbon monoxide by subjecting water gas to suitable catalysts offers much of interest to the gas industry. This method of enriching lean gas for fuel purposes can be expected to solve carburetting problems in certain localities, although the increasing availability of natural gas and of liquefied hydrocarbons forestalls this to some extent.

The manufacture of urea from ammonia and carbon dioxide by subjecting these gases to a pressure of about 100 atmospheres at a temperature of 150 deg. C. has developed commercially in Germany and is undergoing scrutiny in this country. In some respects urea is an ideal fertilizer material, containing over 46 per cent nitrogen. Its wider exploitation in agriculture awaits the education of the farmer in the use of concentrated fertilizer. The manufacture of Wöhler's first synthetic organic chemical from ammonia and carbon dioxide is another triumph of modern high-pressure technique. This reaction has been known for 60 years, having been reported in a German technical publication in 1870, but not until recent engineering developments made it commercially feasible was it seriously attempted on a large scale.



Recent and Remarkable Rise in Production of Synthetic Methanol and Fixed Nitrogen in the United States

Pressure methods for the separation of helium from natural gas has placed the United States in a peculiarly favorable position regarding lighter-than-air transportation. The winning of helium from natural gas has become such an efficient process, due to improved methods and advanced engineering, that sources containing little more than 1 per cent of the gas are now considered "pay" gas. Even more astonishing results may be expected when fundamental data on the properties of gases under pressure are available; such as compressibility, specific heat, and viscosity.

SIMILAR developments have enabled industry to take advantage of the cheap hydrogen found in coke-oven gas. This is particularly true in foreign countries where the byproducts (tar, etc.) of coal distillation have a proportionately larger value than in the United States. The liquefaction of coke-oven gas for separation of hydrogen and return of the residue for the usual uses, has found wide favor in Europe. Present economic conditions do not favor the process here, but a real gain has been registered in solving the engineering and chemical problems involved.

Separation of the constituents of natural gas, producing pure ethane, propane, butane, and other hydrocarbons, has again made available to the chemical industry as raw material extremely valuable compounds. To do this it was necessary to become expert in the application of pressure and temperature control to the rectification of very volatile mixtures. Engineering developments of recent date combined with technical skill of a high order have overcome difficulties, and the expanded production of these compounds awaits only the finding of new uses.

A related development is the application of gas under pressure to the winning of petroleum from oil fields that had previously been considered exhausted. The "gas drive" is bringing more and more fields into profitable production and should be credited to the benefit that increased interest in pressure application has caused.

The progress of high-pressure developments naturally has been greatest in the more strictly chemical industries. An excellent illustration is the change that has come about in the manufacture of phenol. So-called "synthetic" phenol is produced by the action of caustic on monochlorbenzene at a high temperature and pressure. Replacing a process that involved sulphonation and caustic fusion, the new development goes more directly to its object by a cheaper route. The application of this method to the production of other hydroxy compounds seems likely.

Following pressure technique into wider fields we find that, processes involving the disintegration of fibers and cellulose have resulted from the use of high-pressure steam. Commercial products possessing new and desirable properties are the result of the application of these methods in a wide variety of fields. New foodstuffs and insulating materials, catering to widely different needs of man, have a common origin in the chemical engineering that produces them.

The benefits to be derived from the use of high-pressure steam have recently come to be quite generally recognized. We have power plants operating under pressures in the range of 1,300 to 1,500 lb. and finding the benefits and economies resulting therefrom more than compensating for the increased difficulty of operation. The swing toward higher pressures for steam and power generation is very marked. Some of the demand for higher temperature heating media has been answered by the use of mercury, diphenyl, and other substances in place of water. The object in such cases is to obtain high temperatures with the use of lower pressures than steam necessitates.

One can trace the accomplishments of high pressure into many other fields with equally satisfying results. There is sufficient evidence that the chemical industry is now in possession of an effective and flexible tool.

There are certain corollary and somewhat intangible accomplishments of high pressure in the chemical in-

dustry. First among these must be mentioned the new viewpoint and new method of thinking which the chemical engineer has adopted. He has found it possible to cast off much of the traditional and orthodox thinking of his predecessors and is taking more and more advantage of the power so recently placed in his hands. We frequently see results which might be attributed to a kind of direct action on the part of some worker in this field. We can illustrate the point by reference to a specific example. When the organic chemist of fifteen years ago desired to introduce an amino group into a compound his method was to nitrate the compound by the use of mixed nitric acid and sulphuric acid and then to reduce this newly introduced nitro group in some suitable manner producing the amino compound. Today, one of the first methods thought of is the direct action of ammonia or an amine on the compound in question under the influence of high pressures and suitable temperatures and catalysts. Extension of the new methods of thinking will continue to bear fruit. The time may come when some of the unorthodox chemical equations found on freshmen examination papers will supplant the time-honored methods. If, fifteen years ago, the vacuous freshman under high pressure in the classroom, had dissected acetic acid and then carried out its synthesis on paper by simple recombination of the parts, viz:

$$CH_3OH + CO = CH_3COOH$$

he would have been so far ahead of his generation as to receive no credit therefor. High pressure, however, may vindicate him.

A parallel accomplishment of high-pressure developments is found in the field of metallurgy. The requirements of processes recently developed have led the metallurgist into fields involving higher temperatures and severe corrosive conditions. Responding to the demand made upon him, he has done noble work in furnishing new alloys of suitable properties and has been the right-hand man of the chemical engineer in making possible the commercial application of many research results. The chromium steels and nickel-chromium alloys are vitally necessary in scores of the processes of which we speak. Carried along by the enthusiasm of his accomplishments, who knows what the metallurgist may next call forth?

Many of these developments have been possible only through simultaneous development along engineering lines. New types of compressors capable of handling gases at pressures hitherto undreamed of were needed to realize commercial status in at least one synthetic ammonia process. The demand has been met and, in so doing, engineers have emancipated themselves from textbooks and rule-of-thumb design and entered upon an era of new thinking and pioneering. Tubing and piping to serve as the arteries of new pressure processes have been a serious problem. Today we have available satisfactory seamless, drawn tubes of alloy and stainless steels, lined tubing, and piping of all descriptions. Fittings, valves, and miscellaneous accessories to do all that formerly was done at moderate pressures are at hand.

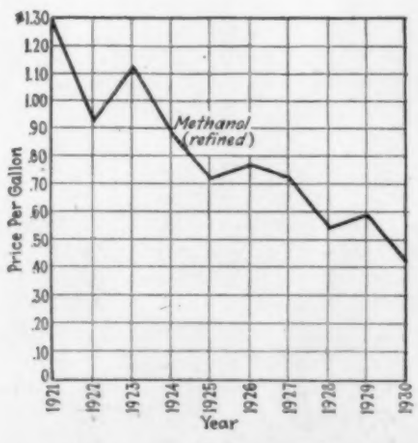
Large pressure vessels, single units weighing 200 tons, have been constructed for pressures to 1,000 lb. and temperatures above 1,000 deg. F. Forgings for pressures to 15,000 lb. are in service. All manner of pressure autoclaves, reaction chambers, heat exchangers, and special vessels can be obtained from manufacturers.

Taking account of the activities of many research organizations we may look to continued progress in the engineering phases of high-pressure applications.

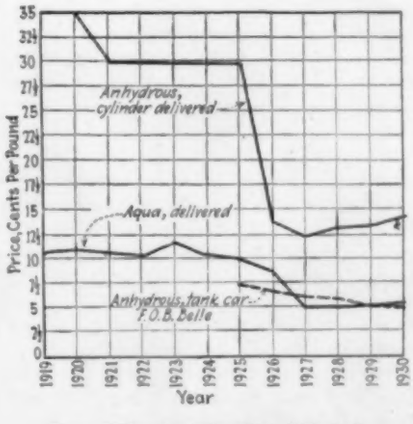
WHAT can be expected in the way of new developments in the near future? It does not require much imagination to predict considerable progress in the field of synthetic organic chemistry which will produce, particularly, aliphatic compounds using water gas and natural gas hydrocarbons as raw materials. Alcohols, acids, aldehydes, and a wide variety of compounds may be expected. Progress inevitably will take the worker into more and more complicated fields. The production of aromatic compounds from aliphatics, such as, for example, benzene from natural gas, is not an unreasonable expectation. This has been forecast by the results of several workers and offers much promise. The hydrogenation of natural petroleum hydrocarbons results frequently in the production of aromatic hydrocarbons of considerable value. It seems likely that the separation and economical production of aromatics from such a source will achieve commercial status in the near future.

The application of high-pressure technique to the unit operations of chemical engineering has already resulted in many benefits. As a specific example of this we cite the case recently reported in the chemical literature by which, in the production of absolute alcohol by distillation of aqueous solutions with benzene, an increase of ten atmospheres in pressure raised the boiling point of the ternary mixture from 65 to 144 deg. and the quantity of water removed by the benzene was 2.6 times as great as at atmosphere pressure. The extension of such work to other systems and the increased application of distillation methods can be awaited confidently.

The electrolysis of water under pressure to generate pure hydrogen for direct use in pressure operations is a fascinating goal. Examination of mechanical gas compression by such methods seems to offer a hopeful prospect. In fact, each new development appears to broaden the scope of chemical engineering in all directions. The chemical engineer is indeed justified in an attitude of optimism toward the future of high pressures.



Declining Prices, the Result of Synthetic Methanol



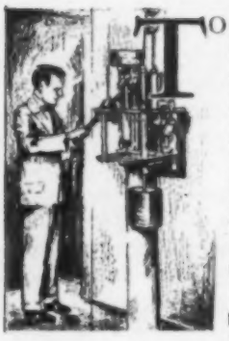
How Nitrogen Fixation Affected Ammonia Prices

RESEARCH

That Paved the Way

For a New Technology

An Editorial Survey of the Non-Industrial Pressure Research Facilities of the United States

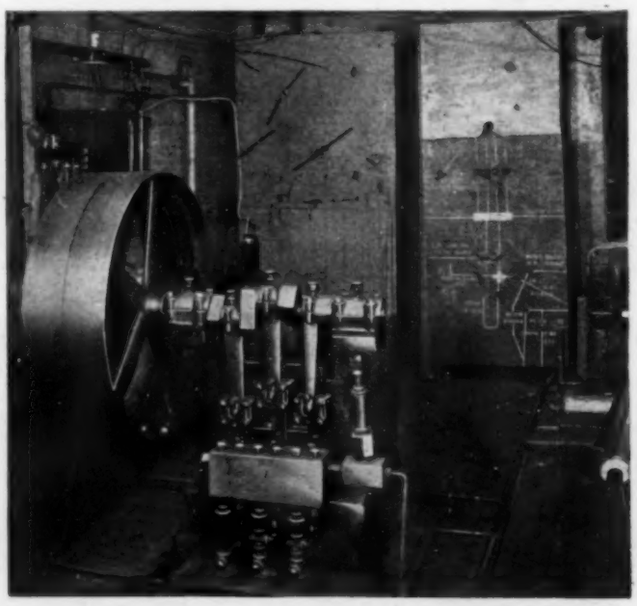


TO WHAT extent have university and government research laboratories contributed to the astonishing progress in high-pressure technology? That the university scientist should pioneer in new fields is the conception and hope of many. But can he be expected to appear prominently in this new development which requires such large research appropriations as well as an intimate mixing of engineering and science? The following answer summarizes the activities of the universities of Wisconsin, Yale, and Illinois, the Massachusetts Institute of Technology, the Fixed Nitrogen Research Laboratory, and the Pittsburgh laboratory of the Bureau of Mines.

In the chemistry department at Madison, Homer Adkins, professor of organic chemistry, is at work with eight graduate students engaged in a variety of researches. Chief among his interests are problems of selective reduction of organic compounds containing more than one reducible group. Published work includes the catalytic reduction of organic compounds using nickel catalysts, and a paper on the condensation of ethanol and acetaldehyde over certain oxide catalysts. The pressure equipment shown in the illustration includes a two-cylinder Watson Stillman hydraulic pump and two vertical water-compression and gas-storage cylinders. A special, slow-feed, double-cylinder liquid pump for introducing organic liquids into the pressure system is available. Several shaking autoclaves for liquid-gas reactions are shown. These are used principally for studying organic reductions.

The high-pressure laboratory of the chemical engineering department at Yale is under the direction of Prof. B. F. Dodge. Since its organization in 1926 it has been engaged principally on problems relating to the synthesis of methanol. In April, 1927, Dr. Dodge accepted a senior research fellowship of Mellon Institute in addition to his teaching and brought the methanol work under the S. Karpen & Brothers fellowship covering the field of synthetic resins. One full-time and one half-time man prosecute this work. Graduate students in chemical engineering have completed and published with Dr. Dodge papers on the equilibrium, decomposition, and synthesis of methanol. The future program contemplates, in addition to extended equilibrium measurements, the collection of fundamental data on physical properties of substances under pressure. A Rix three-stage laboratory gas compressor capable of work at 4,500 lb. pressure, suitable gas holders and hydraulic pump, and a gas storage system designed for 1,000 atm. pressure, together with numerous catalyst and reactor tubes make up the special equipment, some of which appears in the accompanying photographs.

The chemistry department of the University of Illinois organized its pressure work in 1926. Under the direction of Prof. Norman W. Krase, a wide variety of problems was undertaken. Aided by grants, particularly from the Chemical Foundation, Inc., of New York, the laboratory has grown rapidly in size and now provides facilities for 12 graduate students. The problems are of two kinds, one class dealing with the study of organic reactions and supported by graduate research assistantships established by industrial concerns, the other class concerned with the collection of fundamental data on properties such as specific heat, solubility, and conductivity. The published work includes data on the specific heats of nitrogen at high pressures and tem-

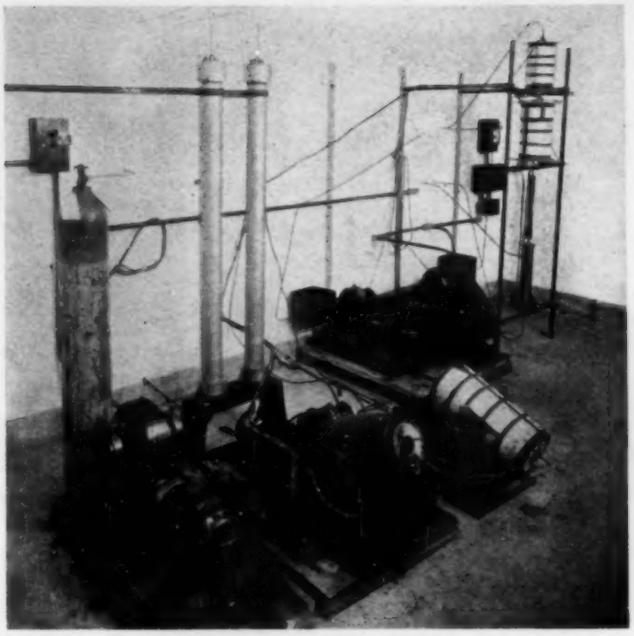


Methanol Research at Yale

LEFT — Hydraulic Pump and Control Panel

CENTER — Control Panel, Piston Gauge and Steel-Clad Gas Storage

RIGHT—Rix 3-Stage Gas Compressor and Hydraulic Hand-Pump



Research Installation at the University of Wisconsin With Shaking Autoclaves in Foreground

peratures, vapor pressure data, and material on the acidity of carbonic acid solutions under pressure. Three papers are in preparation for technical journals. Future plans contemplate continuation of this program with continued emphasis on fundamental studies.

Two 4,500-lb. gas compressors, a hydraulic pump, 1,000 atm. gas storage capacity, large gas holders and provision for four catalyst units, together with a special experimental recirculating unit for "life tests" on catalysts, are installed in a building having a floor space of 30x60 ft.

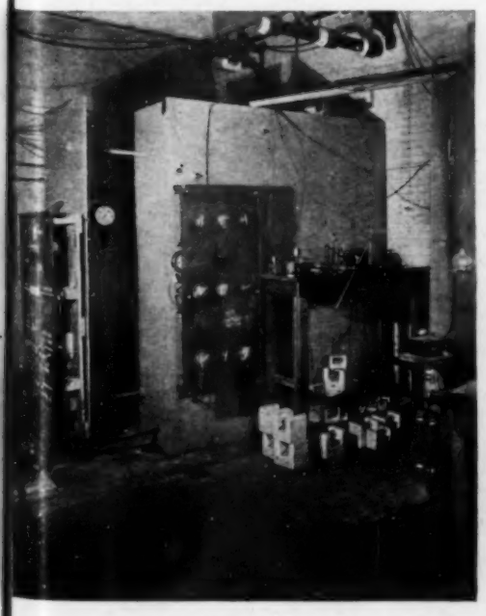
The high-pressure work of the Research Laboratory of Applied Chemistry at the Massachusetts Institute of Technology was started in 1925 with a small number of research workers under the immediate direction of Prof. W. G. Whitman. Primary credit for instigating this program and for developing the industrial contacts which made it possible goes to Prof. R. T. Haslam, now manager of development in the Standard Oil Development Company. Since that time the high-pressure work has grown to where it is at present a large proportion of the laboratory's program and is still rapidly growing.

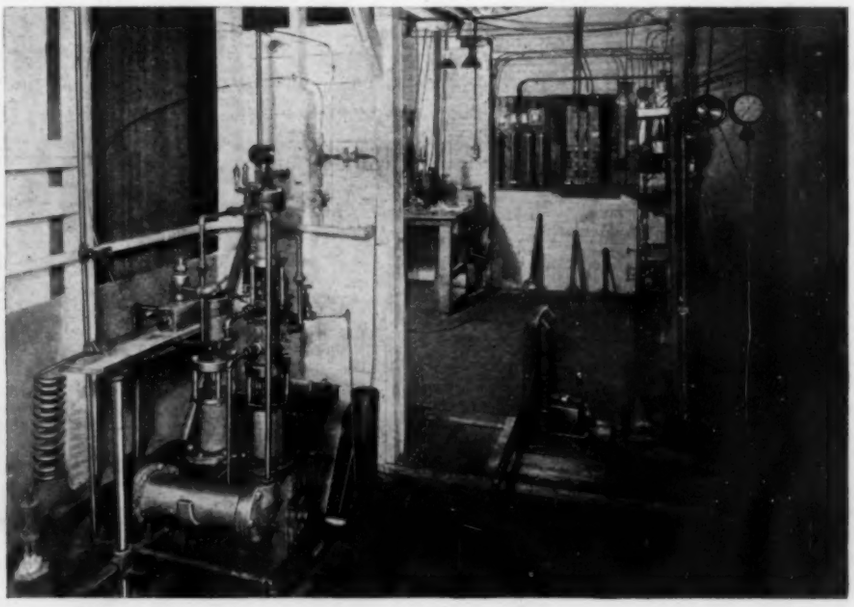
At the present time 20 men are engaged in conducting the high pressure research. Of these, twelve are research men who devote all of their time directly to the high-pressure work. Two are machinists who devote their full time to the construction and maintenance of apparatus, practically all of which is built in the laboratory's machine shop.

The equipment includes such items as reactors for flow experiments, bombs for static runs, high-pressure liquid pumps, valves, orifices, connectors, and a deadweight gage which has been built for use in experiments requiring very accurate pressure measurement. The photographs show some of the permanent physical equipment of the high-pressure laboratory.

Since the beginning of this high-pressure work the greatest part of the research has been of a confidential nature done under contract for industrial concerns. Notwithstanding the fact that this unpublishable work has occupied the greater part of the time, considerable research of an independent and public nature has always been carried out. Thesis work dealing with different phases of the problem of methanol and higher alcohol synthesis from hydrogen and carbon monoxide has resulted in several publications. A study has been made of the application of high pressures to reactions involving aromatic hydrocarbons, and the effect of pressure and temperature on the rate of reaction and equilibrium of the reaction of benzene to form diphenyl and hydrogen. Likewise, a study was made of the decomposition of benzene to carbon and hydrogen under pressure. An extensive study has been made of the rate of diffusion of hydrogen through palladium as a function of temperature, pressure, and thickness of metal. As a direct result of these experiments, catalyzed reactions of liquid benzene with such gases as carbon monoxide, carbon dioxide, methane, and ethylene at high pressures and temperatures under 300 deg. C. were investigated. A study of the viscosity of gases under high pressure has resulted in the accumulation of further valuable data.

A vapor pressure chart of the lower aliphatic hydrocarbons has been developed from data partly available in the literature and partly derived from experimental results in the laboratory. The effect of temperature and pressure on the upper explosive limits of methane-oxygen mixtures has been determined. Publications are pending on the solubility of gases in liquids and on





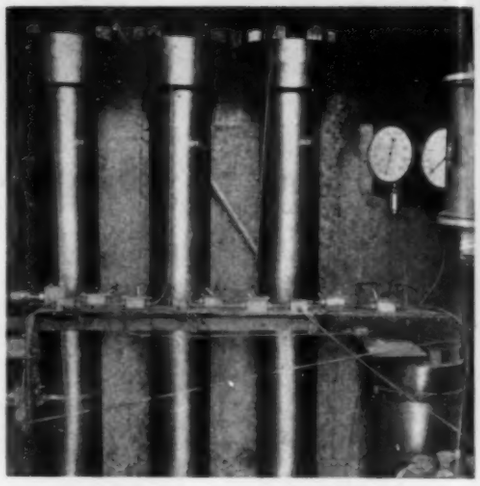
the adsorption of gases on charcoal at pressures up to 3,000 lb. per square inch.

The temperature coefficients of solubility of various gases in several different liquids under high pressures are being determined. Work is in progress on a study of the thermodynamic properties of hydrocarbons up to relatively high temperatures and pressures. Considerable work is being done on the cracking of hydrocarbons, some of which, such as the cracking of naphthalene under hydrogen to form benzene, is at high pressure.

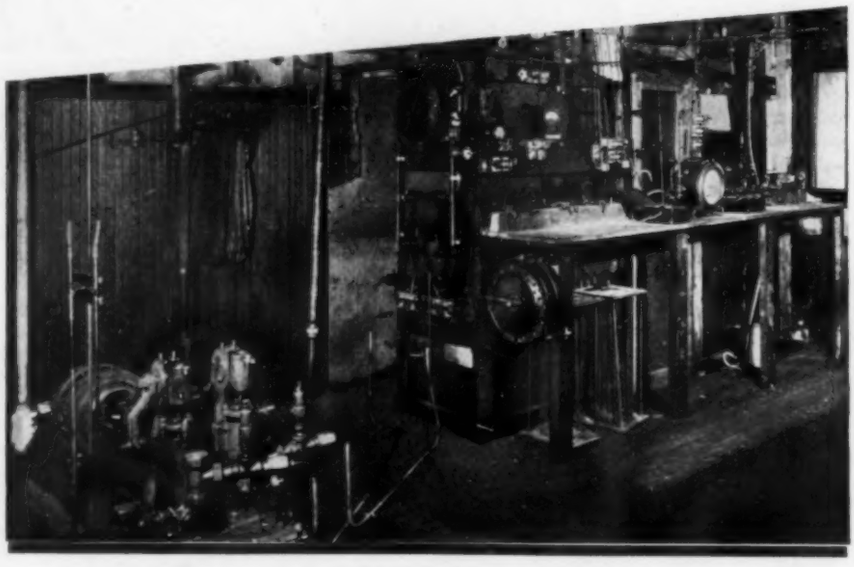
Contemplated work includes such subjects as the effect of pressure on the rate of reaction in certain systems, new gas and vapor phase reactions, fundamental properties and behavior of materials under high pressures, such as miscibility of liquids, diffusion of gases, and the like. The development of new types of apparatus, of better means for measuring rates of flow of gases and liquids under pressure, and of better means for conducting the experimental work is constantly in progress.

The Fixed Nitrogen Research Laboratory of the Bureau of Soils and Chemistry, organized originally by order of the Secretary of War in March, 1919, and later transferred to the Department of Agriculture, is the pioneer in high-pressure research in the United States. Directed in turn by such men as Dr. A. B. Lamb, Prof. R. C. Tolman, and Dr. F. G. Cottrell, invaluable results have been accomplished. Concentrating its pressure work on the development of synthetic ammonia catalysts, it designed and operated a half-ton test plant for several years. The catalyst type developed ranks among the best known today. Later work, particularly under the direction of Dr. E. P. Bartlett, resulted in the publication of compressibility data on nitrogen, hydrogen, mixtures of these gases, and carbon monoxide—material of fundamental importance to industry. Present problems include a continuation of the compressibility measurements on helium, a study of gas solubilities, and certain engineering problems having relation to the design of high-pressure compressors.

The value of this government laboratory to the country cannot be judged alone by its impressive list of published papers. Not the least of its contributions has been the training of research men for the industries. Practically none of the successful pressure plants in the United States is without a "Fixed Nitrogen" alumnus, and several large companies organized their pressure research staffs around a nucleus of such men. Thus the Atmospheric Nitrogen Corporation now counts J. M. Braham, F. A. Ernst, D. C. Bardwell, M. F. Fogler, and E. D. Crittenden on its staff; Commercial Solvents employs L. A. Stengel; and the DuPont Ammonia Corporation is represented with A. T. Larson, R. L. Dodge, Roger Williams, and J. A. Almquist. That the laboratory has been able to accomplish outstanding work in spite of periodic "raids" on its personnel by industry is a tribute to its spirit and directive leadership.

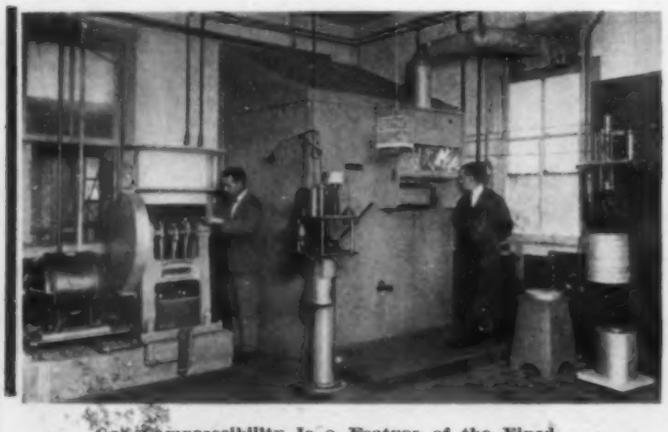


Forged Cylinders for High-Pressure Gas Storage at Illinois



Hydraulic Pump and Gas Control at Massachusetts Institute of Technology

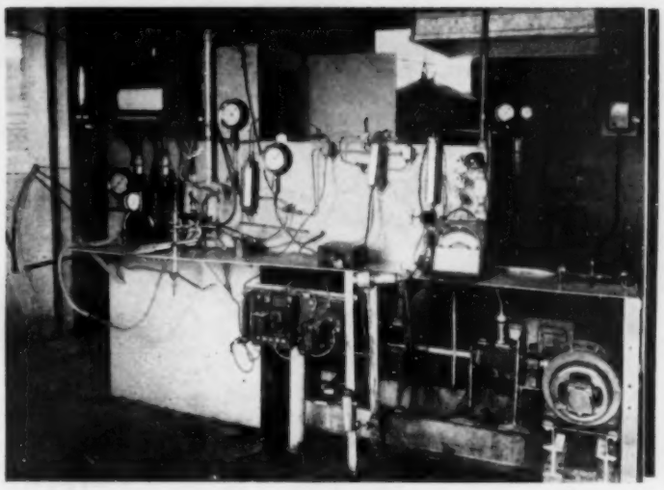
Research on the synthesis of hydrocarbons, alcohols, and other possible motor fuels is a part of the work of the physical chemistry section of the Pittsburgh Experiment Station of the U. S. Bureau of Mines. It is one phase of the Bureau's study of the utilization of coal. The work has been carried on



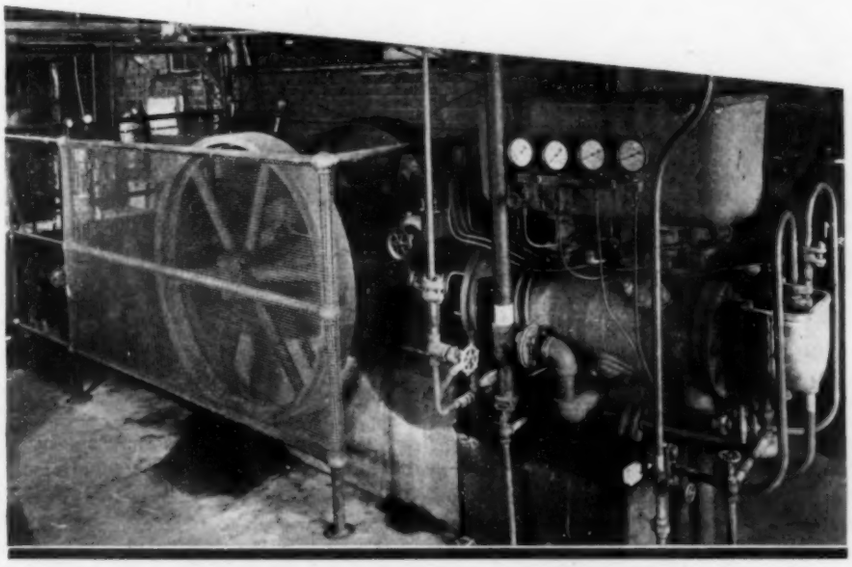
Gas Compressibility Is a Feature of the Fixed Nitrogen Research Laboratory's Studies

Experimental Plant for Synthetic Urea at Fixed Nitrogen Laboratory

High-Pressure Research Laboratory of the University of Illinois

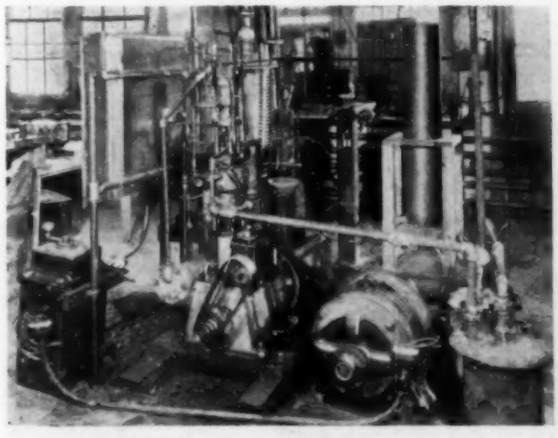


Gas Recirculation for Catalyst Testing at Illinois



Norwalk Horizontal Gas Compressor at Laboratory of Massachusetts Institute of Technology

with the normal staff of the physical chemistry section and only one or two men have been engaged on high-pressure research. This has been done for the government to provide itself in a general way with first-hand information on reactions and processes bearing on the production of liquid fuels from coal.



Ammonia and CO_2 Compressors in Fixed Nitrogen Research Laboratory

Before starting the experimental work, a thermodynamic study was made of the equilibrium conditions in the formation of hydrocarbons and alcohols from water gas.

The results of this study were published by David F. Smith (*Ind. Eng. Chem.*, 19 1927, 801-803). This study was followed by an experimental investigation of the catalytic effect of various substances in decomposing methanol at atmospheric pressure. These results were then published by David F. Smith and Charles O. Hawk (*J. Phys. Chem.*, March, 1928, 415-424).

In the meantime, an apparatus was set up in which pure carbon monoxide and hydrogen could be circulated under high pressure over the catalyst, which could be heated to any desired temperature up to 450 deg. C. A number of experiments were conducted with zinc oxide, basic zinc chromate, and normal zinc chromate catalysts. The basic and the normal zinc chromate, as indicated in the decomposition experiments, proved the more active catalysts. With the normal zinc chromate at 400 deg. C. and 180 atm., and in a theoretical mixture of hydrogen and carbon monoxide, an experimental conversion of the latter to methanol of about 20 per cent has been attained. The results of this investigation were published by Ralph L. Brown and A. E. Galloway (*Ind. Eng. Chem.*, 20, 1928, 960-966). Further experiments showed that a copper-chromium oxide catalyst in contact with a 2:1 hydrogen-carbon monoxide mixture yielded, in addition to methanol, large quantities of dimethyl ether. These experiments are reported by Ralph L. Brown and A. E. Galloway (*Ind. Eng. Chem.*, 21, 1929, 310; 22, 1930, 175).

During the last two years the work of this laboratory has been directed toward an experimental determination of the equilibrium between methanol, carbon monoxide, and hydrogen. A preliminary paper was published by David F. Smith and B. F. Branting (*J. Am. Chem. Soc.*, 51, 1929, 129), followed by a paper by David F. Smith and Lester L. Hirst on the "Reliability of the Heat Data as a Factor in Calculating Equilibria Involving Methanol" (*Ind. Eng. Chem.*, 22, 1930, 634-635). Another paper, entitled "The Reactions Which Occur on a Methanol Catalyst," was presented by Smith and Hirst at the meeting of the American Chemical Society in Cincinnati, on Sept. 8, 1930.

It is expected that the physical chemistry section of the Pittsburgh station will continue fundamental research on high-pressure reactions with especial reference to fuel problems.

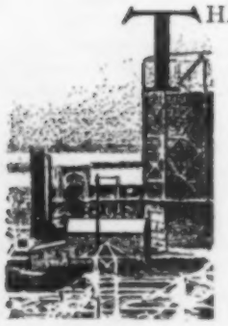
The special high-pressure equipment consists of two small, three-stage compressors.

Some Aspects of

Nitrogen Economics

By CHAPLIN TYLER

DuPont Ammonia Corporation, Wilmington, Del.



THAT world overproduction of nitrogen exists today and in fact has existed throughout 1930 is a condition that does not require statistical proof. It is common knowledge that stocks of nitrogen products—both of Chilean nitrate and of synthetic-nitrogen fertilizers—have increased to a point where curtailment of production has been forced, either by lack of storage facilities or by the realization that carrying charges on excess inventories would nullify any possible profit. The principal immediate results of world overproduction have been a substantial fall in prices of nearly all nitrogen products, particularly of such fertilizers as sulphate of ammonia; the consummation of world agreements involving all major producers of nitrogen excepting only those of the United States; and a precipitate reorganization and plans for the all-inclusive rationalization of the Chilean nitrate industry.

An examination of production statistics for some years past reveals some significant trends. The charts appearing herewith (with the exception of Fig. 5) are based on statistics presented by Col. G. P. Pollitt before the Second World Power Conference in Berlin. It is believed that these statistics are as reliable as any that have been published previously—if not more so. The curves have been plotted on semi-logarithmic paper in order to facilitate the estimation of rates of growth.

Fig. 1 represents the world production of byproduct nitrogen and Fig. 2 represents the production of Chilean nitrate, both for the years 1903-1929 inclusive, and expressed as thousands of metric tons of nitrogen.

For the eleven-year period 1903-1913 inclusive, both curves show surprisingly constant rates of increase. During the war period, byproduct nitrogen was produced in fair accordance with the rate of increase established previously. Chilean nitrate production suffered temporary reverses, owing largely to the hazards of ocean shipping and loss of important markets. After the war, there occurred a severe and prolonged reaction in the production of both these forms of nitrogen, particularly of Chilean nitrate. Comparing these curves, it is reasonable to expect greater stability in production of byproduct nitrogen, the output of which is dependent largely upon activity in the steel and manufactured gas industries. The extremely erratic course of Chilean nitrate production during the post-war period reflects the competition from synthetic-nitrogen fertilizers, particularly those produced in Germany.

The rapidity with which synthetic nitrogen has become dominant in the world industry is illustrated by Fig. 3. The rise and decline of the arc process is shown clearly, and there is no reason to believe that a revival will occur. Since 1923 the cyanamid industry has more than doubled its output, which for 1929, however, was not more than one-quarter as much as that from ammonia synthesis. In the nine years from 1920 to 1929 the production of nitrogen by the ammonia synthesis increased elevenfold; from about 100,000 metric tons to about 1,100,000 metric tons per year.

With Figs. 1, 2, and 3 in mind, it is interesting to examine Fig. 4, which shows the world production of all forms of inorganic nitrogen from 1903 to 1929 inclusive. Here several striking trends are disclosed. The rate of increase in

Figs. 1 and 2—World Production of Byproduct Ammonia and Chilean Nitrate (Both Expressed as Nitrogen)

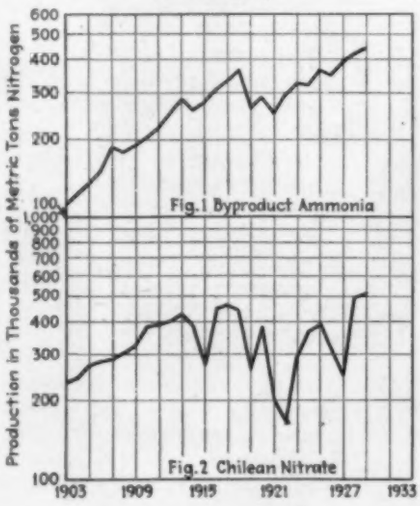
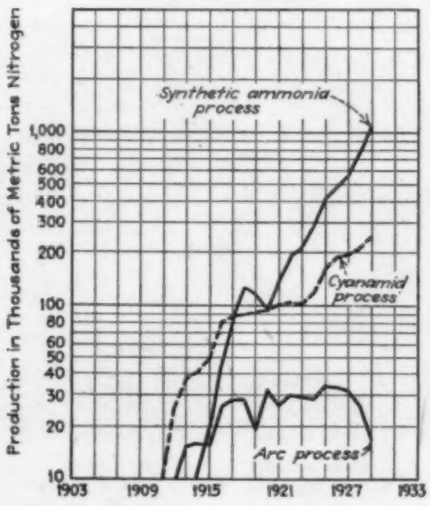


Fig. 3—World Production of Nitrogen by Arc, Cyanamid, and Synthetic Ammonia Processes (Expressed as Nitrogen)



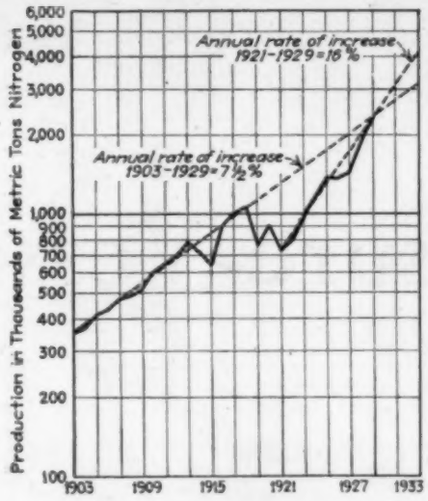


Fig. 4—Total World Nitrogen Production, Showing Rates of Increase

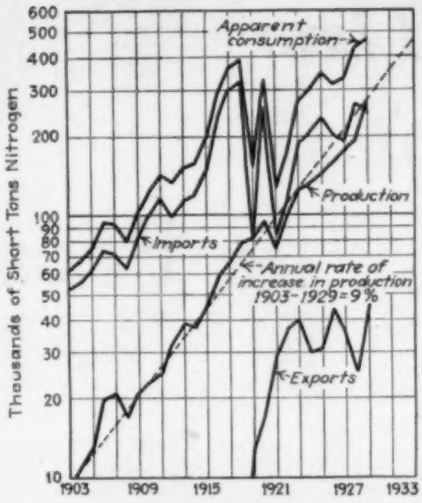


Fig. 5—United States Nitrogen Production, Consumption, and Trade (Expressed as Short Tons of Nitrogen)

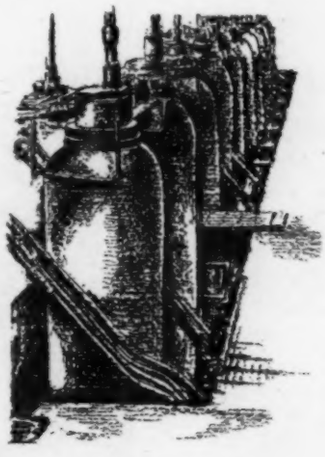
production for the period 1903-1918 was 7½ per cent per year with but one large deviation, that occasioned by the war. It should be noted that the estimated production for 1929 falls on the extrapolation of the 7½ per cent rate of increase curve which held for the period 1903-1918.

For the period 1921-1929, which might be termed the post-war recovery period, the rate of growth is much greater, being about 16 per cent per year. Apparently, the urge to extend this excessive rate of growth indefinitely was a fundamental cause of the nitrogen crisis now being faced overseas. This situation should serve to drive home to all participants in the nitrogen industry the desirability of keeping expansion programs within the bounds of reasonable rates of growth.

Now that the nitrogen industry has attained a size adequate to supply the world's needs at low prices, it is improbable that further growth will be as spectacular as that witnessed recently. During the period of history just considered, there was a real deficiency of inorganic nitrogen, and this deficiency could be satisfied only by nitrogen at prices lower than those prevailing prewar. Unquestionably, the large-scale and world-wide development of the ammonia synthesis has induced, if not actually forced, reductions in the cost of producing nitrogen by other means.

The production history of the nitrogen industry in the United States, shown in Fig. 5, is considerably different from that of the world nitrogen industry, shown in Fig. 4. Normally, world production must equal world consumption, although not necessarily is this true year for year. Accepting this approximation, it can be seen that the curves for world consumption (world production) and U.S.A. consumption are similar in their courses. However, the U.S.A. production curve is much smoother than the world production curve, particularly for the war and post-war periods. For the entire period 1903-1929 the rate of increase in production for the U.S.A. was 9 per cent per year, compared with the world rates of 7½ per cent during 1903-1918 and 16 per cent during 1921-1929.

Last year, for the first time United States nitrogen production actually exceeded nitrogen imports. It is clear, therefore, that the present nitrogen crisis is not of alarming consequence to the U.S.A. That is to say, a condition of overproduction, now prevailing generally in the world, fundamentally does not exist here. If the world produces more nitrogen, it must consume more; if the U.S.A. produces more nitrogen, it will import less, provided of course, that costs of production here and abroad are anywhere near comparable. There is reason to believe that some recent offerings of imported sulphate of ammonia represent scarcely a break-even price to the producers. Such a situation is fortuitous to the consumer and certainly does not foreshadow further reductions in nitrogen prices.



THE TOTAL U.S.A. output of synthetic ammonia is now believed to be at the rate of 500 short tons of ammonia per day, or equal approximately to the total capacity of 520 tons per day estimated by *Chem. & Met.* editors, in the January, 1930, issue. Current output, therefore, is equivalent to 180,000 short tons of ammonia per year of 360 days. Furthermore, the capacity of plants now built, building, and immediately projected is estimated to be only slightly less than 1,000 tons of ammonia per day, equivalent to 360,000 tons of ammonia per year of 360 days.

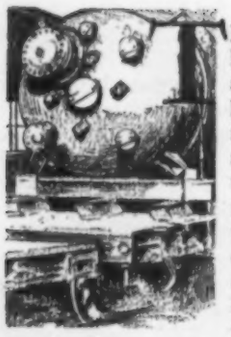
This enormous increase in prospective capacity is due largely to announcements of plant expansion by the Atmospheric Nitrogen Corporation (subsidiary of the Allied Chemical & Dye Corporation) at Hopewell; by the Du Pont Ammonia Corporation at Belle, W. Va.; and the new plant to be built by the Shell Chemical Company (subsidiary of the Shell Development Company) near Pittsburg, Calif. The Shell plans, as announced in the press, call for two units, each of 10,000 metric tons of nitrogen per year. Thus the equivalent capacity of the two units as ammonia would be 75 short tons per day. Further progress has been made at the Belle, (W. Va.) works of the Du Pont Ammonia Corporation, the present capacity of which is about 200 tons of ammonia per day, not including high-pressure units for the synthesis of methanol and higher alcohols on a large scale. The Du Pont company, through the recent acquisition of the Roessler & Hasslacher Chemical Company, has increased capacity to the extent of the established ammonia plant at Niagara Falls, N. Y. The only other important development is the new plant of the Midland Ammonia Company at Midland, Mich.

When the above projects are completed, as probably will be the case before the end of 1931, it is believed that the minimum investment in U.S.A. synthetic ammonia and immediately integrated works will be in excess of $70,000,000, and a more probable figure is $80,000,000, a sum which should indicate roughly the comparatively large capital requirements of the typical high-pressure synthesis industry.

Correlating Theory and Practice in Pressure-Vessel D

By NORMAN W. KRASE

Chemical Engineering Division
University of Illinois, Urbana



TRENDS toward higher pressures and temperatures have resulted in increased interest and concern on the part of those responsible for the design and construction of equipment for such severe service. This attitude is dictated not only by the potential hazard to life and property but also by a desire to take full advantage of the economies rendered possible by the new conditions. High-pressure processes are characterized by very large capital investments, and the need for efficient operating units is, therefore, accentuated. In this article an attempt is made to review the principles of design, to discuss the selection of materials and to point out successful methods of fabrication and of testing pressure vessels. Much of this material was kindly furnished by the A. O. Smith Corporation, of Milwaukee, pioneer in the application of arc welding to the construction of high-pressure equipment.

Design — A review of the fundamentals of design of pressure vessels is necessary to an understanding of the difficulties encountered when very high pressures and temperatures are involved. It is, of course, readily seen that this type of design is concerned entirely with thick-walled vessels and that these act very differently from thin-walled. The principal reason for this is that the latter are more free to adjust themselves to shape under pressure without producing excessive metal stress.

A simple stress-pressure relation may be developed by considering the hollow cylinder, shown in Fig. 1, under an internal pressure, P. The area in tension is $2\,tL$ and the area under pressure is DL. If S is the tensile stress developed then

$$2\,tLS = PDL \text{ or } S = \frac{PD}{2t}$$

Considering the ends of the cylinder, the area in tension is πDt and the area under pressure is $\frac{\pi D^2}{4}$. If this pres-

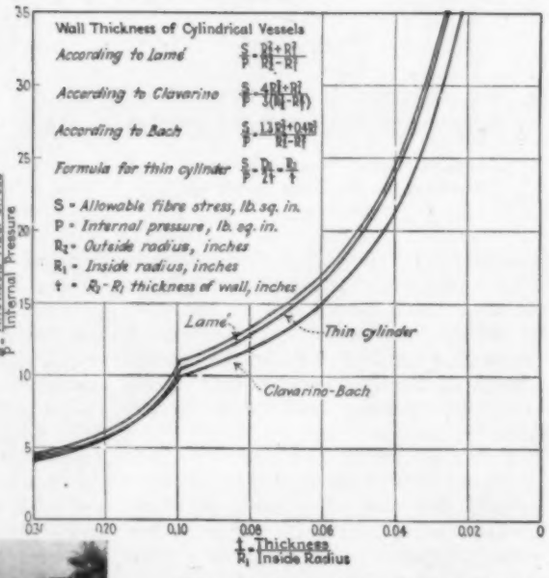
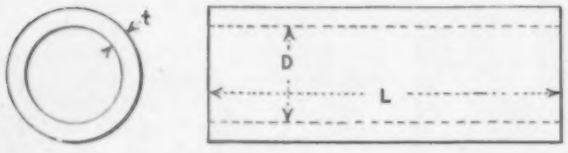


Fig. 2—Comparison of Formulas for Calculating Stress and Wall Thickness

Fig. 3 — Unique Transportation Methods Used in Trinidad

Fig. 4—Thick-Walled Welded Sphere Subjected to Failure Test; Note That Cracks Do Not Follow Welds

Fig. 1—Ideal Hollow Cylinder Dimensions for Developing Stress-Pressure Formula



el Design

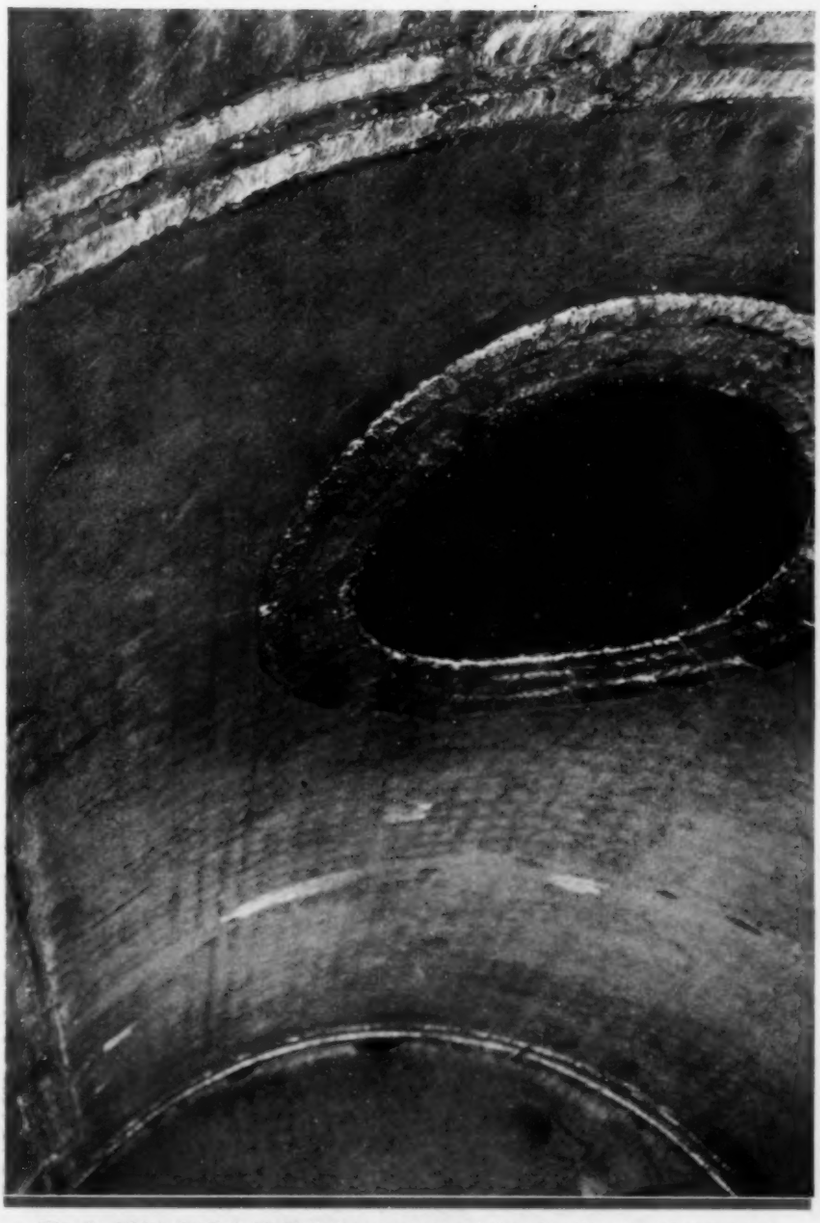


Fig. 5—Thick-Walled Welded Pressure Vessel Interior Showing Reinforcing of Opening and Bottom of Welds

sure develops a stress, S, in the material

$$\pi DtS = \frac{\pi D^2}{4} P \text{ or } S = \frac{PD}{4t}$$

and it is seen that the longitudinal stress is just one-half the circumferential stress. This applies only to thin-walled vessels and is within a small percentage of being correct.

These formulas are based on simple mechanics and assume a perfectly elastic material as well as uniform stress distribution in the cylinder. No allowance is made for a concentration of stress such as might occur due to improperly shaped ends or weakened areas where openings are made in the vessel. These points will be considered presently.

It is one thing to calculate allowable stress and another to use it correctly. Differences have existed for many years among engineers concerning the mechanism by which failure occurs in steel. Briefly stated, the theories are as follows:

Maximum stress theory (Rankine) assumes that failure is due to the largest single stress, without reference to other co-existing stresses. Although generally admitted to be incorrect it is, nevertheless, considerably used in boiler design. *Maximum strain theory* (Saint-Venant) assumes a given limit to deformation and that failure occurs when this ultimate unit deformation is reached. *Maximum shear theory* (Guest-Hancock) assumes that a material reaches its elastic limit in tension or compression when the unit shearing stress reaches the elastic limit of the material in shear, and failure occurs when the unit shearing stress reaches the ultimate shearing strength of the material.

Space does not permit extended discussion of these theories. It is entirely possible that each has its range of application and that a complete understanding of the phenomena of combined stresses involves the best thought expressed in all three statements. For example, Becker, in Bulletin 85 of the University of Illinois Engineering Experiment Station, concludes that the maximum strain theory holds up to the shearing yield point, and above this the maximum shear theory holds. In brief, considering a pressure vessel with various openings and changes in section, and with heads of the usual shape and with given methods of joining sections, the application of the mathematical relation of shape and discontinuity to the theory of elasticity is almost impossible even to the most expert mathematician. It seems certain, however, that the peculiarities associated with steel will behave according to the necessarily intricate formulas if these are properly applied and sufficiently well understood.

The theories mentioned have resulted in a number of applications of methods in calculating the dimensions of pressure vessels, particularly the wall thickness required to develop a given stress. In Fig. 2 are shown the formulas and comparative results, graphically. For a given ratio of allowable stress to working pressure the formula of Lamé is most satisfactory, since it gives the largest and therefore the safest ratio of wall thickness to inside radius and, furthermore, conforms most nearly with destructive test results. The Clavarino formula is based on the maximum strain theory of failure and is essentially similar to that of Bach.

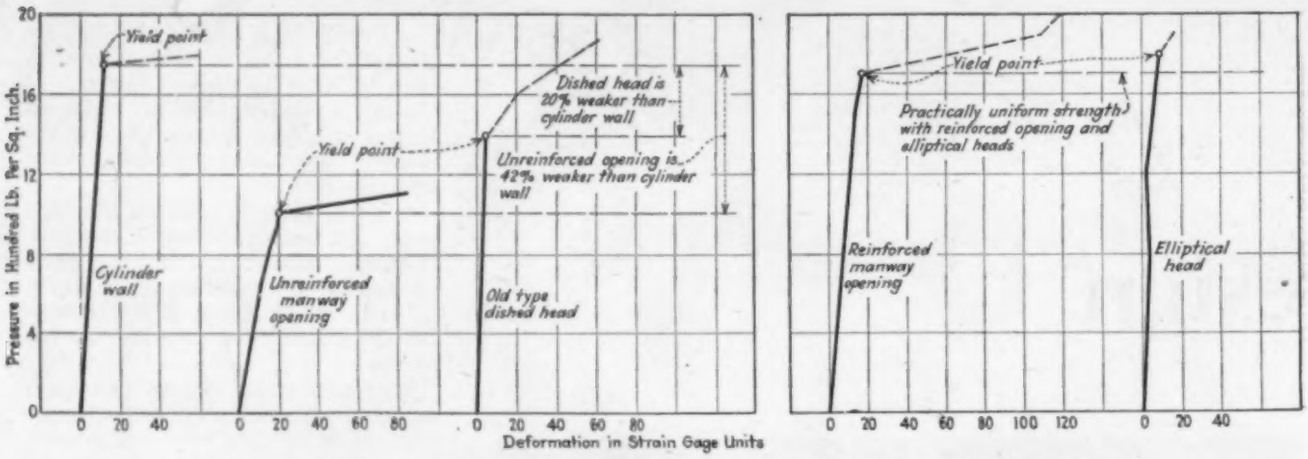

Pressure in Hundred Lb. Per Sq. Inch.
Yield point
Cylinder wall
Yield point
Unreinforced manway opening
Dished head is 20% weaker than cylinder wall
Unreinforced opening is 42% weaker than cylinder wall
Old type dished head
Deformation in Strain Gage Units
Yield point
Practically uniform strength with reinforced opening and elliptical heads
Reinforced manway opening
Elliptical head

Fig. 6—Test Results Showing Effect of Reinforcing and Head Design on Vessel Strength

The serious question of head design and of reinforcing openings must be solved experimentally by actual tests on a variety of vessels. Fig. 6 shows actual results obtained using a vessel having a 6-ft. diameter, 40-ft. length, and a 2-in. wall thickness. Two types of heads and various degrees of reinforcing were used at openings to obtain these data. The pressure-strain relations for the cylinder wall were taken at a point sufficiently removed from any discontinuity to test the simple cylinder formula. The pressure at the indicated yield point of the cylinder was 1,740 lb. An unreinforced manway opening showed a yield point 40 per cent below this and an ordinary dished head at the most stressed portion yielded 26 per cent below the main cylinder strength. Subsequent tests on properly reinforced openings and elliptical heads gave the results shown. The yielding in each case occurred at the same stress in the steel; the reason why yielding occurred at different pressures in the unreinforced openings and in the dished head was stress intensification caused by improper design. These facts are an excellent illustration of the importance of design in removing intensification factors due to discontinuity and shape requirements.

Materials and Fabrication — Correct design is of little avail unless the material used measures up to all requirements and the process of fabrication produces a vessel conforming to the desired shape, free of fabrication stresses. Steels for high-temperature, high-pressure service should meet specifications on chemical composition, physical properties at working temperatures, corrosion resistance, and long-time service conditions. The questions of steel composition and corrosion are somewhat related, although it is well known that steel under stress exhibits different—and frequently accelerated—corrosion tendencies as compared with an unstressed sample. In the field of alloy steels, particularly those of high chromium and nickel content, heat-treatment is particularly important, especially when the intended service does not involve high temperatures.

The forming of thick plates for pressure vessel construction is best carried out hot. Also, after forming and joining plates and completing the vessel, fabrication strains should be relieved by heating to insure a well-balanced stress condition under working load.

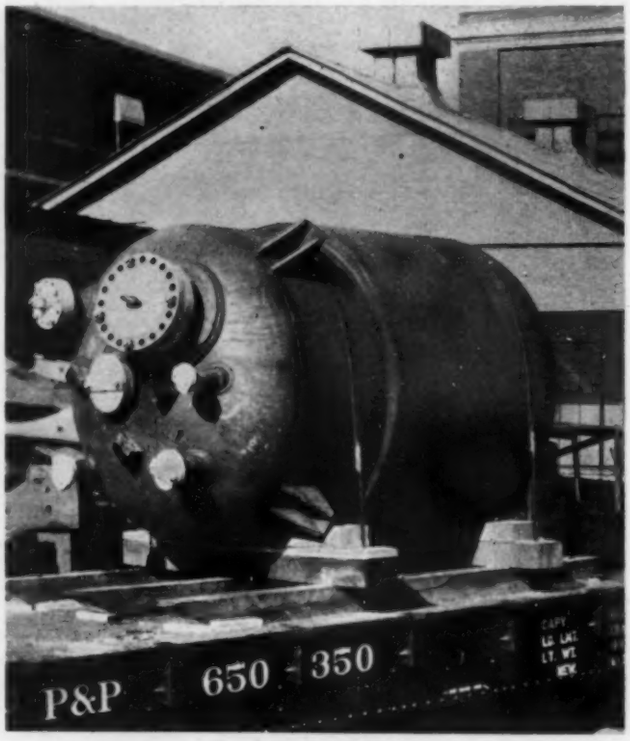


Fig. 7 — Jacketed Autoclave for Chemical Process Work. Reinforced Openings and Connections as Well as Jacket Entirely Are Welded

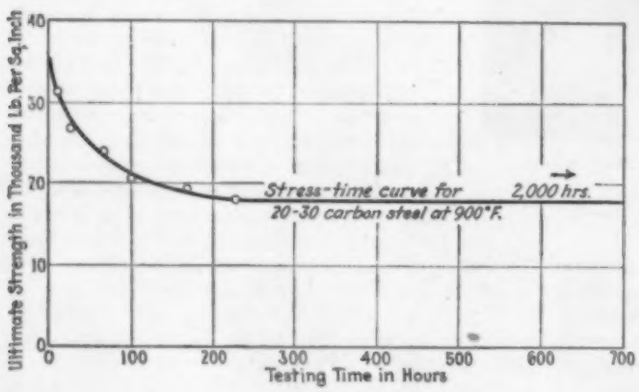

Ultimate Strength in Thousand Lb. Per Sq. Inch
Stress-time curve for 20-30 carbon steel at 900°F.
2,000 hrs.
Testing Time in Hours

Fig. 8—Long-Time Test of Steel at Elevated Temperature Necessary for Calculation of True Safety Factor

No attempt will be made here to compare riveting, forging, and welding methods in the fabrication of pressure vessels. At the present time each has its field, sometimes overlapping others and furnishing a competitive condition that promises to stimulate development

and research to the ultimate benefit of the pressure industry in general.

Testing—The only certain way of determining how strong a vessel is, is to test it to failure. This procedure is the last criterion of design and fabrication theories and practice, and, while sometimes very costly, must be undertaken at intervals as a part of the testing program. In addition, there are many installations, operating under severe corrosive conditions, where periodic proof-testing is advocated to detect deterioration in service and thus prevent loss of life and property.

By far the largest number of tests, however, must be made on a laboratory scale with a view to correlating such data with full-scale tests. Present practice in modern laboratories permits close simulation of service conditions in the matters of temperature, pressure, and corrosion. In addition to the familiar and more or less routine measurements such as tensile strength, elongation, hardness, ductility and others, the selection of steels for high-pressure, high-temperature use involves a knowledge of the maintenance of these properties over long periods. Life tests under service conditions are necessary. "Creep" phenomena, until recently little appreciated, are of vital importance in this matter. While there is yet much difference in opinion regarding the proper method of interpreting and using creep data, there is general agreement on the importance of this property of steels at elevated temperature. Reference to F. H. Norton's book on "Creep of Steel at High Temperatures" is suggested for details and data. It can be said for the present that the ultimate, long-time strength of steel, which is sometimes only one-half the short-time strength, should be the basis for safe stress and safety factor calculations. The following table illustrates both the time and temperature effect on two common steels:

Ultimate Tensile Strength

	0.08 to 0.12 Per Cent Carbon		0.2 to 0.3 Per Cent Carbon	
	short time	long time	short time	long time
70 deg. F.....	49,000	49,000	59,000	59,000
900 deg. F.....	32,500	15,000	35,300	18,000

Fig. 8 illustrates the effect of time on the ultimate strength of a common steel when subjected to stress at 900 deg. F. The "long-time" value reached, in this case, after about 300 hours, is the only dependable basis for safety factor calculation under such conditions.

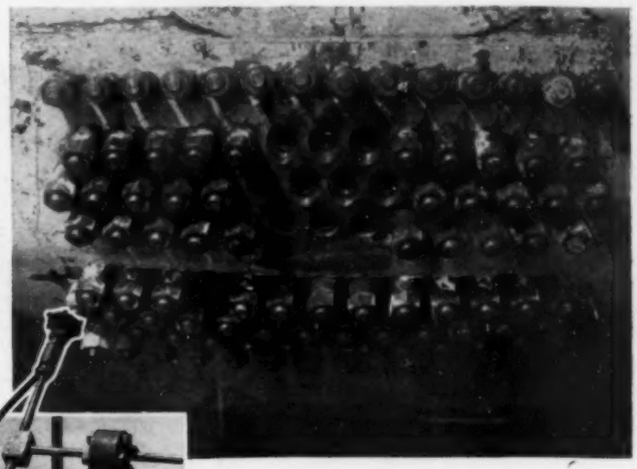


Fig. 9—Right: Distortion of Holes After Test at Nine Times Operating Pressure

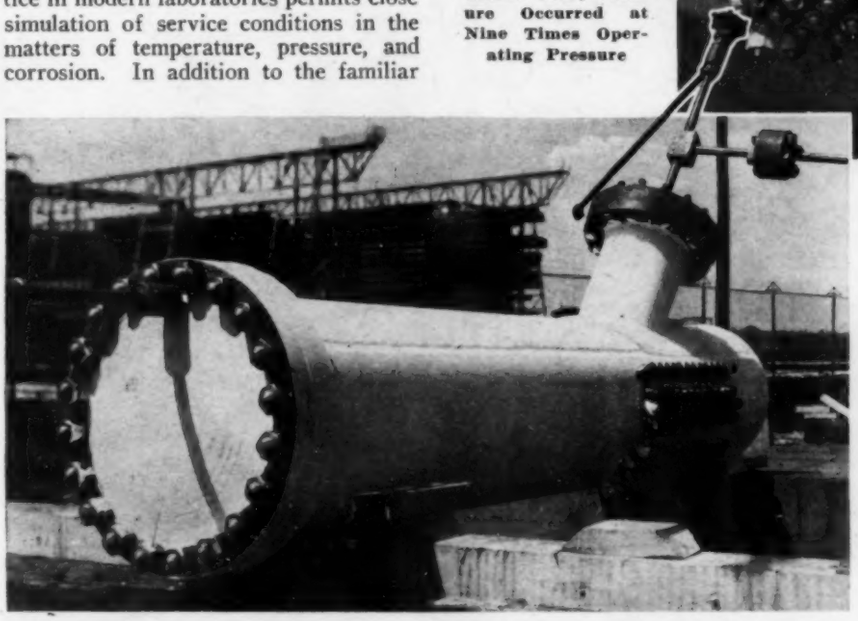


Fig. 10 — Below: Navy Superheater Under Test; Failure Occurred at Nine Times Operating Pressure

The question of fatigue tests involving the resistance of metals to repeated or alternating stresses is not of great significance in pressure vessel design. Operating conditions do not fluctuate sufficiently or rapidly enough to bring this factor into importance.

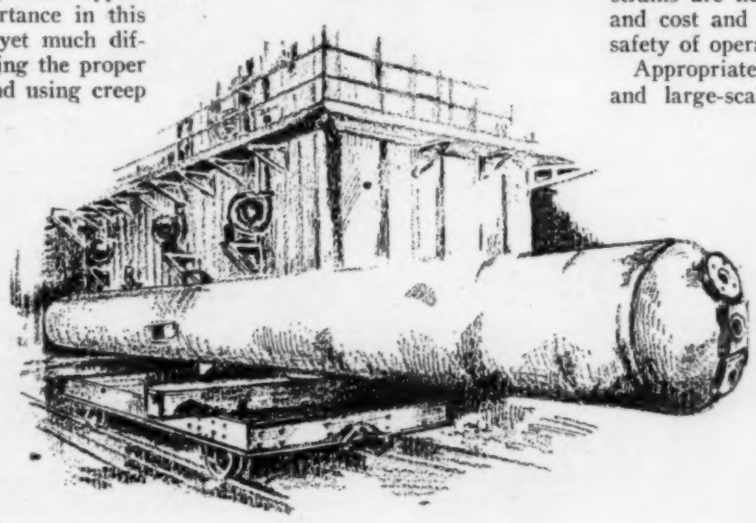
The points particularly pertinent in the construction of high-temperature, high-pressure equipment may be summarized briefly as follows:

The strength of each part of the vessel should be so balanced by proper design that no stress concentration exists and there is no "weakest" part. Elimination of the factor of ignorance in the factor of safety is essential.

Careful selection of materials, with emphasis on physical and chemical properties under service conditions, is a milestone on the path to successful production of safe vessels.

Fabrication methods which produce a homogeneous product having 100 per cent joint strength with no fabrication strains are necessary to reduce weight and cost and to promote economy and safety of operation.

Appropriate testing, both laboratory and large-scale, insures soundness of design and places the stamp of approval on all factors concerned in the production of pressure vessels. Periodic proof testing during the life of vessels in operation precludes failure due to severe service conditions.



Where High Pressures *Are Being Applied In* American Industries

Principal United States Plants for High-Pressure Synthesis

HIGH PRESSURES and temperatures find their most spectacular industrial application in chemical synthesis. In the United States at the present time there are perhaps 25 or 30 plants engaged in pressure syntheses of one type or another. In addition, there are literally hundreds of applications of high pressures or high temperatures, or both, in petroleum cracking, natural and manufactured gas production and distribution, compressed and liquefied gas plants, and in related operations of the process industries. Only the principal pressure synthesis plants, however, are shown on the accompanying map and tabulation.

Most important among the strictly pressure industries are those for the fixation of nitrogen through the direct synthesis of ammonia from its elements. Pressures varying from 200 to 1,000 atmospheres find application in this industry. The largest nitrogen plants are at Hopewell, Va., and Belle, W. Va.—sites chosen primarily because of proximity to coal, the source of hydrogen. Around Niagara Falls, at Midland, Mich., and Windsor, Ontario, plants have been or are being built to use the byproduct hydrogen from electrolytic alkali plants. On the Pacific Coast, a substantial development is under way to supply the growing demand of that region.

Methanol and other organic chemical syntheses are only at the beginning of an impressive development. At Belle, W. Va., alcohols are produced as joint products in ammonia synthesis. By-product gases from carbide furnaces at Niagara and from fermentation tanks at Peoria, Ill., furnish raw materials for the remainder of the methanol production.

Elsewhere in this issue are detailed articles, halftones, and editorial discussion of the high-pressure synthesis operations carried on in the plants of the Atmospheric Nitrogen Corporation, Du Pont Ammonia Corporation, Commercial Solvents Corporation, Carbide & Carbon Chemicals Corporation, Mathieson Alkali Works, and the Stand-Oil Company of New Jersey.

Company	Location	Product	Approximate Pressure, Lb. per Sq.In.	Estimated Capacity (Jan. 1, 1930), Tons per Day
Atmospheric Nitrogen Corp.	Hopewell, Va.	Ammonia	3,000– 4,000	300
		Nitrate of Soda		800
	Syracuse, N. Y.	Ammonia		40
Du Pont Ammonia Corp.	Belle, W. Va.	Ammonia	10,000–15,000	150
Mathieson Alkali Works..*	Niagara Falls, N.Y.	Ammonia	4,000– 4,500	15
Roessler & Hasslacher Chem. Co....	Niagara Falls, N.Y.	Ammonia	4,000– 4,500	8
Pacific Nitrogen Corp.	Seattle, Wash.	Ammonia		3
Great Western Electro-Chemical Co.	Pittsburg, Cal.	Ammonia	4,000– 4,500	4
Midland Ammonia Co.*	Midland, Mich.	Ammonia	4,000– 4,500	8
Shell Chemical Co.*	San Francisco, Cal.	Ammonia, sovents..	4,500– 9,000	80
Consolidated Smelt. & Refining Co...	Vancouver, B. C...	Ammonium phosphate	3,000– 4,000	260
Canadian Industries, Ltd.*	Windsor, Ont.	Ammonia	4,000– 4,500	8
				Gal. per Year
Du Pont Ammonia Corp.	Belle, W. Va.	Methanol, sod. form.	10,000–15,000	2,000,000
Commercial Solvents Corp.	Peoria, Ill.	Methanol	4,000– 4,500	2,500,000
Union Carbide & Carbon Co.	Niagara Falls, N.Y.	Methanol	4,000– 4,500	.....
Carbide & Carbon Chem. Corp....	Charleston, W. Va..	Solvents	.....	.....
E. I. du Pont De Nemours	Parlin, N. J.	Solvents	.....	.....
Du Pont Ammonia Corp.	Belle, W. Va.	Solvents	10,000–15,000	.....
Dow Chemical Co.	Midland, Mich.	Phenol	4,000– 5,000	.....
				Bbl. per Day
Standard Oil Co. of N. J.	Bayway, N. J.	Petroleum products	3,000– 5,000	5,000
Standard Oil Co. of Louisiana	Baton Rouge, La..	Petroleum products	3,000–5,000 (Experimental)	100

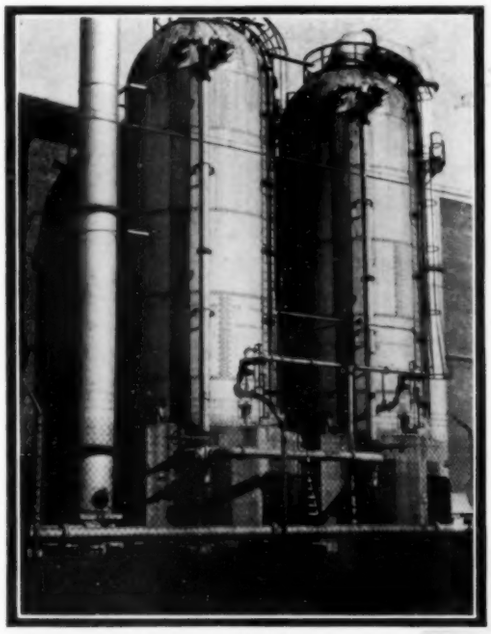
*Under construction.

America's Largest Plant

For Nitrogen Fixation

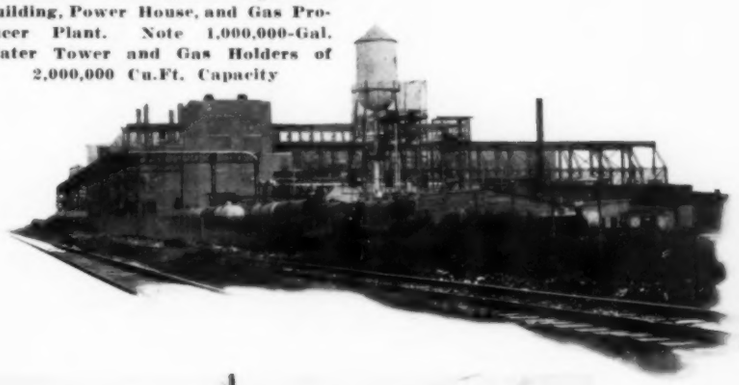
Section of Hopewell, Va., Showing Huge New Works of the Atmospheric Nitrogen Corporation

© Aero Service Corporation



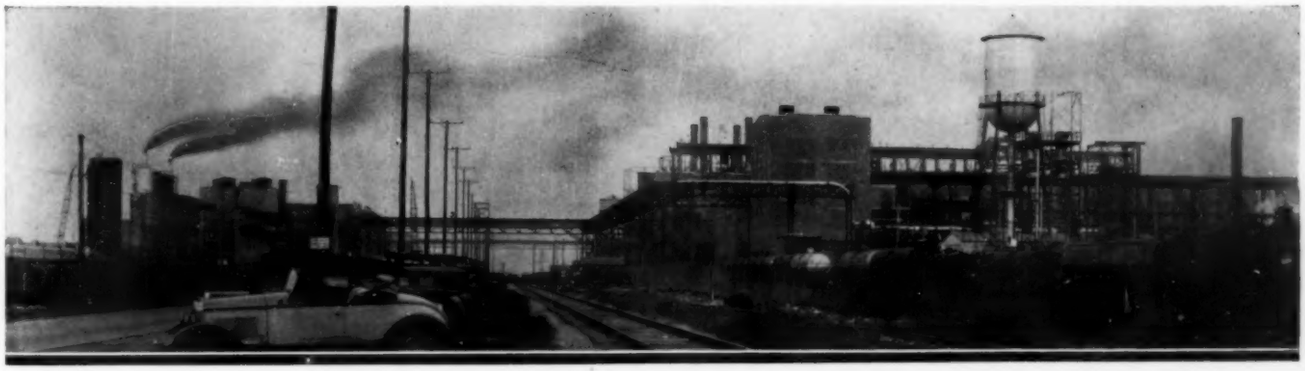
Receivers Through Which Ammonia Is Pumped en Route to Oxidation Units

Ammonia Synthesis Units. Catalyst Building in Foreground, Followed by Ammonia Converters, Recovery and Purification Buildings, Compression Building, Power House, and Gas Producer Plant. Note 1,000,000-Gal. Water Tower and Gas Holders of 2,000,000 Cu.Ft. Capacity



Where Ammonia Is Oxidized to Synthetic Nitrate of Soda. Note Chromium-Steel Nitric-Acid Towers

View From Public Highway, Showing "Synthesis Section" on the Right and "End Products" or "Nitrate Section" on the Left



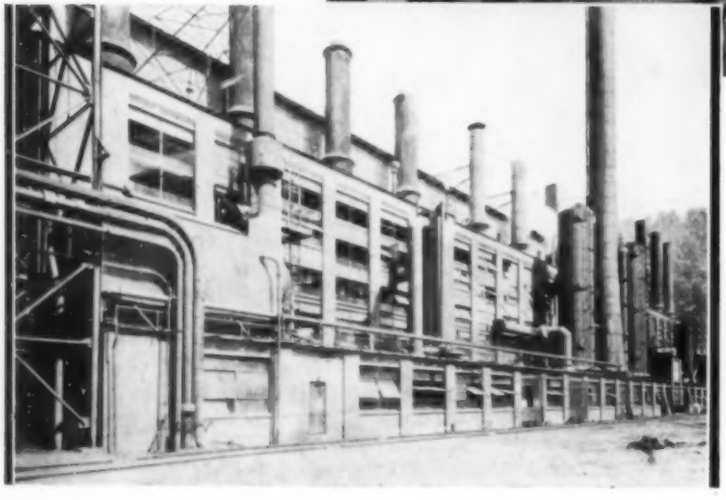
Central Portion of Belle Works. Main Synthesis Buildings Run Parallel to Kanawha River. Water-Gas Generator House and Steam Plant Are at Right.

High-Pressure Synthesis

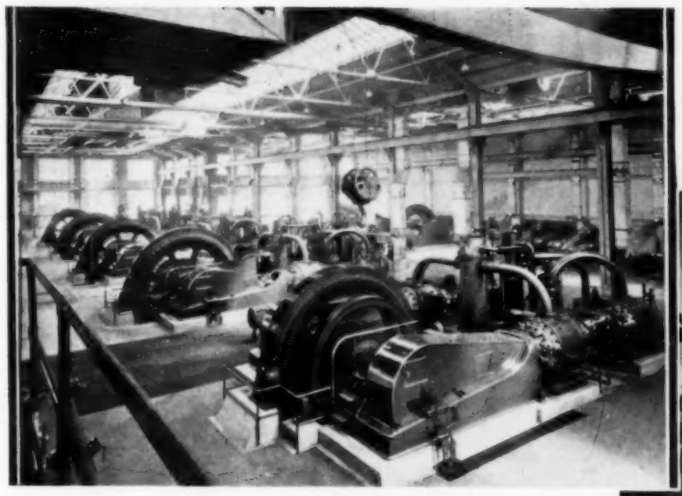
at Belle (W. Va.) Works of the Du Pont Ammonia Corporation

Power Recovery System for Regeneration of Water Used in Pressure Scrubbing Operations. About 60 Per Cent of the Power Used in Scrubbing Is Recovered in This Mountain Return System.

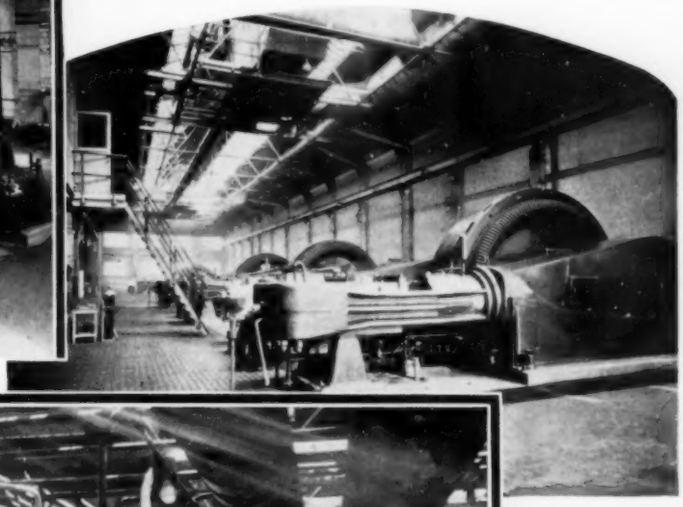
Charging Floor of New Byproduct-Coke Plant Comprising 46 Ovens. The Excess Gas Will Be Used as Boiler Fuel.



Water-Gas Generator House. Total Capacity of Generators Is About 70,000,000 Cu.Ft. Blue Water Gas Per Day. Coke Is Produced in the Company's Own Byproduct Ovens Several Hundred Yards Distant.



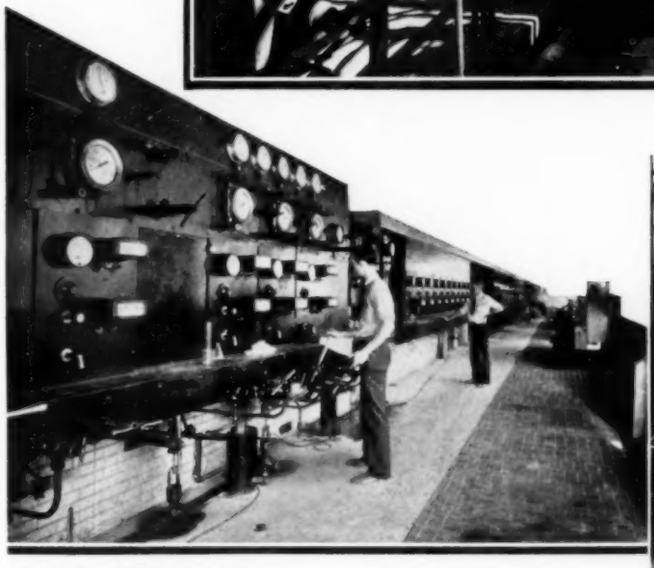
The Gas Compressors at Left Compress Gas to 25 Atmospheres, at Which Pressure Part of the Purification Operations Is Effected



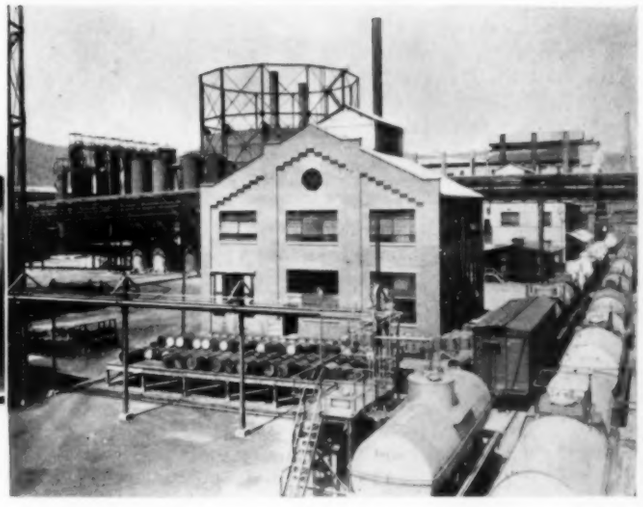
Synthesis Building, Showing High - Pressure Receivers and Piping

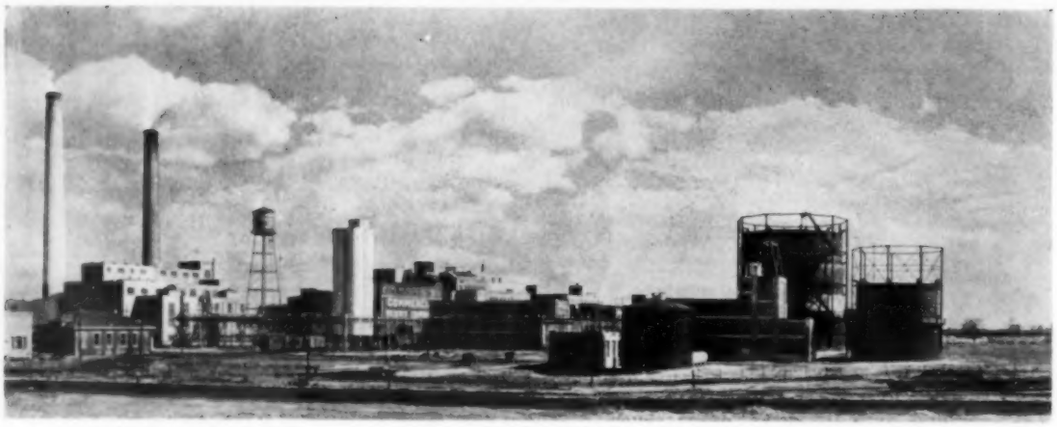
The Hypercompressors Above Are Three-Stage Machines. The Intake Pressure of the First Stage Is 25 Atmospheres and the Final Discharge Pressure Is About 1,000 Atmospheres

In Foreground of the Factory Yard Below Is the Filling Station for Both Drum and Tank-Car Shipments of Synthetic Methanol and Anti-Freeze Solutions



Synthesis Building, Showing Control Board and Sampling Outlets



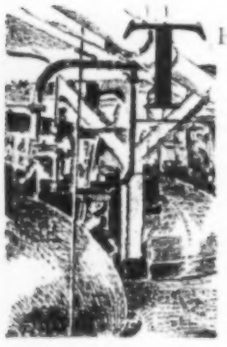


Commercial Solvents Plant, Showing Methanol Department and Gas Holders at Right

Synthesizing Methanol

From Byproduct Gases

EDITORIAL STAFF ARTICLE



THOUGH it was one of the first pressure operations on a large scale in this country, the synthetic methanol plant of the Commercial Solvents Corporation at Peoria, Ill., is still one of the largest and most modern installations of its kind. It exemplifies very strikingly what the development of pressure technique has meant to many companies in this country. During the war and for some time afterward, the activities of this company were confined principally to the fermentation of corn for the production of acetone, butanol, and ethyl alcohol. A byproduct of this fermentation was a very large volume of gas consisting approximately of 40 per cent hydrogen and 60 per cent carbon dioxide by volume.

In 1925 this gas was worth only its fuel value and apparently there was no other more profitable outlet for it. With the accumulation of knowledge, resulting principally from developments during the war, the potential value of byproduct hydrogen became more generally appreciated. The production of synthetic ammonia from nitrogen and hydrogen which had been prosecuted so successfully in Germany and which was rapidly developing in this country, became an accomplished industrial fact. The research department of the corporation, alive to the possibilities opened up by this new development, began experimentation and evolved a successful process for the production of methanol from corn fermentation gas. This process, which has reached its fruition in the plant at Peoria, will be briefly described.

The gas leaving the fermentation tanks is piped to the solvent recovery plant where it is stripped of its volatile components by means of active carbon. This adsorption process is well known and similar methods are used in other plants, so it will not be considered in detail. The stripped gas now passes to the main methanol synthesis building for further treatment in preparation for the process. It has been found experimentally that the best conditions for methanol formation from hydrogen and either carbon dioxide or carbon monoxide involve the use of a considerable excess of hydrogen in the gas. The first step, therefore, is the adjustment of the composition to meet this requirement. Taking advantage of the much greater solubility of carbon dioxide in water as compared with hydrogen, this is readily accomplished by water scrubbing the gas under a pressure of about 250 lb. The operation involves two-stage compression in Allis-Chalmers or Nordberg machines which discharge into the lower ends of large, cylindrical steel towers packed with iron rings to furnish wet surface. Scrubbing water enters at the top.

The compression of moist carbon dioxide is not without its problems, however, because of corrosive action, and it has been found necessary to employ stainless steel valves and other special compressor parts in order to overcome the difficulties. Two types of scrubbing towers are in use; one is an electric arc-welded vessel manufactured by the A. O. Smith Corporation, the other is of riveted construction.

The aqueous solution of carbon dioxide from the scrubbing operation goes to a large steel tank where a release of pressure allows the gas to come out of solution. A recent development involves piping this carbon dioxide to a plant of the Dry-Ice Corporation for the manufacture of this new refrigerant. The water, now freed of dissolved gas, is pumped back to repeat the scrubbing cycle. The re-use of water is not dictated by a desire to economize in this regard but rather to avoid the introduction of fresh water with its accompanying dissolved air which is obviously undesirable when mixed with hydrogen and carbon monoxide under pressure. The gas leaving the scrubbing operation is approximately 75 per cent hydrogen and 25 per cent carbon dioxide and is stored in large, water-sealed gas holders, as shown in accompanying illustrations.

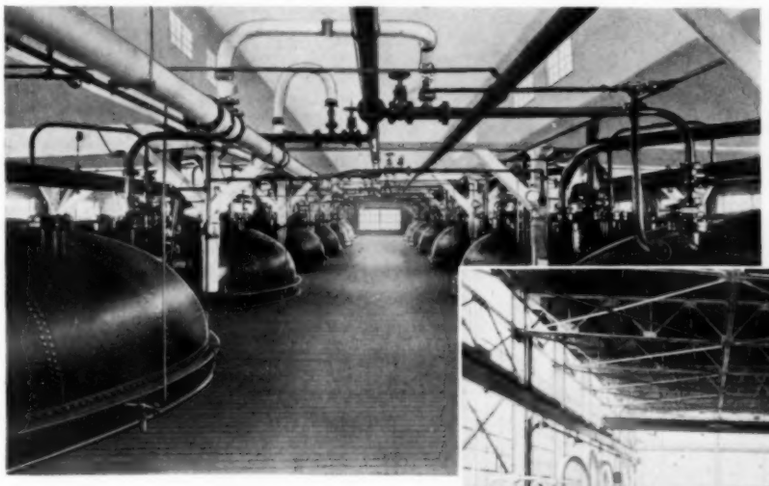
The pressure synthesis cycle begins

by taking gas from storage through meters to the intake of six-stage compressors. Here again Allis-Chalmers and Nordberg machines are used. The pressure ordinarily used in this plant is about 4,500 lb. per square inch and the gas leaving the last stage of the compressors passes through oil traps and entrainment separators to a manifold which supplied the synthesis system. Before entering the converter proper, the gas is warmed up in passing through heat exchangers by means of the hot gas coming out of the converter. In addition to this, a heat exchanger inside the converter itself brings the entering gas to the proper temperature before it reaches the catalyst.

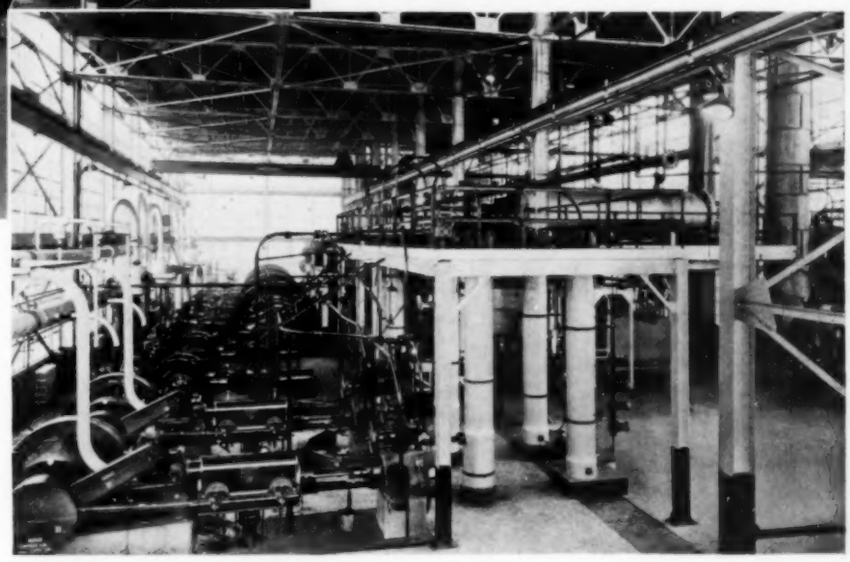
The temperature regulation on this operation is accomplished by a controlled bypass of part of the gas around the internal heat exchanger. In the formation of methanol and water from carbon dioxide and hydrogen there is sufficient heat liberated, due to the exothermic character of the reaction, to keep the catalyst up to the desired temperature when the converter is well insulated. The heat effect in this reaction is considerably less, however, than in the synthesis of ammonia from nitrogen and hydrogen and a much higher space velocity is permissible, therefore, than in the case of ammonia synthesis. If the same space velocity were used in ammonia synthesis as is now used at the Commercial Solvents plant, the liberation of heat would be at an uncontrollable rate.

The gas leaving the catalyst passes out around the heat exchanger inside the catalyst tube and then through the external heat exchanger and through coolers and condensers. Methanol is condensed out by simple water cooling and separated. The non-condensable gas is recirculated by means of a single-stage booster compressor which makes up the pressure drop in the system. This pump discharges back to the original manifold into the circulatory system just described. As is the case in all the reactions of carbon dioxide, carbon monoxide, hydrogen, etc., where a large number of compounds can theoretically be formed, there are a number of side reactions which go on to produce other compounds. Among these might be mentioned methane, which accumulates to a certain extent in the recirculated gas. After a certain period of operation, however, the composition of this recirculated gas is essentially constant.

The condensate from this process is approximately 65 per cent methanol and 35 per cent water, which goes to the alcohol refinery. The alcohol is collected in tanks placed on scales so that the rate of production of alcohol is immediately available at all hours of the day by means of a visible indicator.



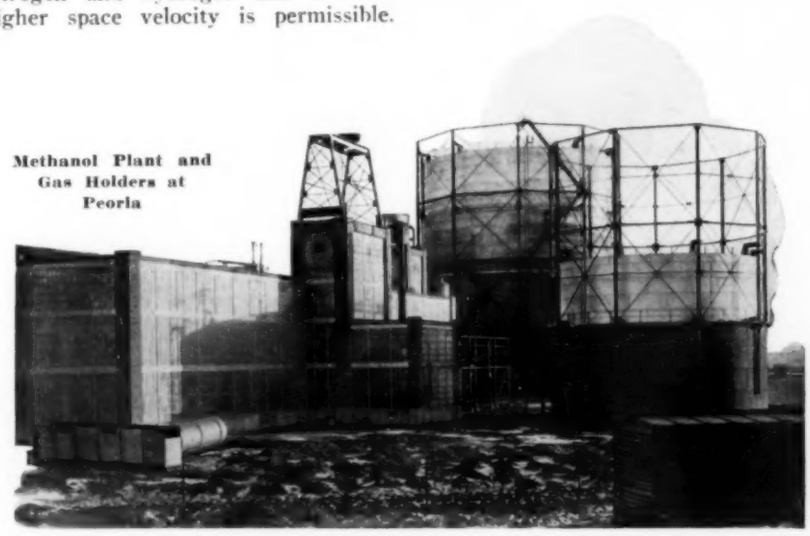
Tops of the 96 Fermenters From Which Gas for Methanol Synthesis Is Evolved



Main Room of Methanol Plant Showing Two-Stage Compressors

A remarkable feature of the plant is that practically every unit is duplicated. This provides at all times spare equipment which can be used in case of a breakdown anywhere along the line. In accord with new developments in the field of alloy steels, the plant is gradually being changed over so that stainless-steel tubing, fittings, valves, and the like are being installed as replacements are made. Corrosion is a serious factor at several stages in this process. The use of a recirculating system involves the ever-present necessity of measuring the rate of flow of gas under pressure. The Commercial Solvents Corporation has solved this problem by the use of a Republic pressure flow meter, described elsewhere in this issue.

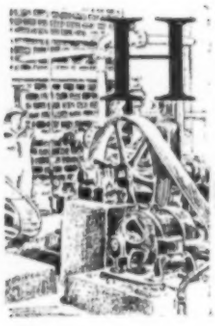
Chem. & Met. wishes to thank the officials of the Commercial Solvents Corporation for their many courtesies and for permission to study the plant and to publish this brief description.



Methanol Plant and Gas Holders at Peoria

The Government's New Helium

By C. W. SEIBEL
Supervising Engineer,
U. S. Bureau of Mines
Amarillo, Texas



HELIUM, the non-flammable gas used for floating lighter-than-air craft, is produced commercially, only within the United States. Since this gas is a very important material for the national defense, it is not strange that the government itself initiated the present industry, built experimental plants during the war, and fostered its entire development up to the present time.

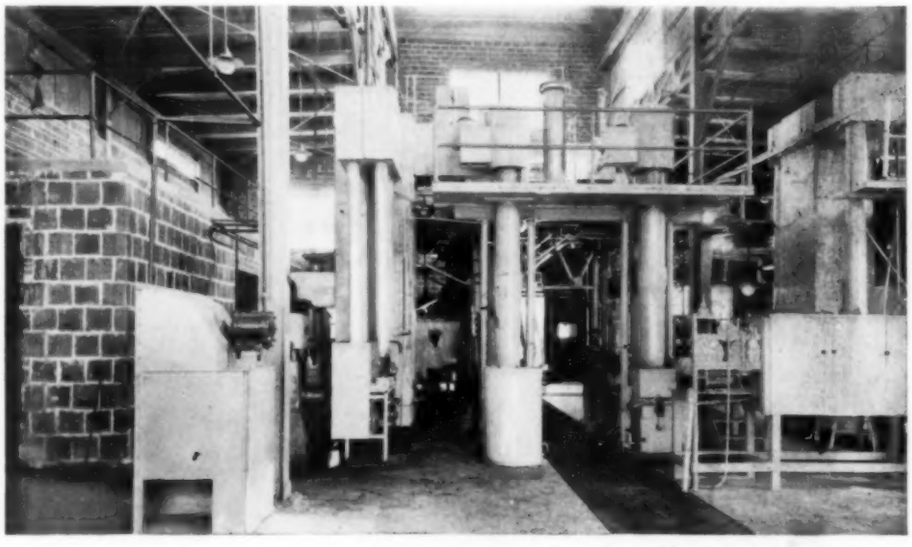
The government's new helium plant, located on an eighteen-acre site, some seven miles from the town of Amarillo, Texas, has just completed its first fiscal year's operation. During this period, all existing records for purity of the product, quantity of production, and price have been broken. The plant itself was designed by government engineers, who also supervised its construction, and is operated entirely by government employees. This plant is perhaps one of the government's most self-contained institutions.

The Bureau of Mines, Department of Commerce, has charge of all helium production for the government. Through this agency, control was obtained of the gas rights of a virgin gas field comprising some fifty thousand acres. The gas reserves of this area are adequate to supply the Army and Navy with helium for many years. Not only does this field produce gas containing nearly 2 per cent helium but the pressure is such that there is no need to compress further the gas in the process of helium extraction. The field is connected to the plant with a 6-in. welded steel pipe line about twelve miles in length. There are four wells on the structure which furnish gas to the plant. Since all four are not needed at any one time they are used in rotation. The government has a trained personnel which looks after the field and pipe line and takes care of the metering of the gas to the plant and also the residue gas which after processing is sold to a gas company for domestic and industrial consumption in the city of Amarillo.

The natural gas which the plant processes has a rather high carbon-dioxide content for fuel gas, about one-half of one per cent, and it is necessary to remove this constituent before the helium can be separated. Failure to do so would result in solidifying the carbon dioxide in some of the tubing and thus putting the plant out of operation.

The removal is accomplished by scrubbing the gas under pressure with a 6 per cent solution of caustic soda. This scrubbing is effected inside of a 4-in. pipe having a total length of about 1,000 ft., and through which all of the incoming gas to the plant must pass. The caustic soda solution is forced into the gas stream with the aid of a plunger-type pump. After the gas and liquid have traveled the length of the 4-in. pipe they are separated in a special trap. The caustic solution is automatically removed from the trap and returned to low-pressure storage tanks. When the liquid solution has become spent it is re-causticized by the use of lime, the resulting solid calcium carbonate removed by a mechanical thickener, and the solution again returned to a storage tank. The removal of the CO_2 by this means is quite effective, and the gas as it leaves this section of the plant contains only a trace of this troublesome material.

The gas, still under pressure, is then conveyed to the building in which the helium is actually removed. The gas coming to the separation building consists chiefly of methane, ethane, nitrogen, and somewhat less than 2 per cent of helium. In order to separate the helium and get it in a nearly pure state, it is necessary to cool the mixture to an exceedingly low temperature. The fact that the gas reaches the plant from the field at a pressure of something more than 650 lb. obviates the necessity of further compression. Practically all of the gas which enters the plant at ordinary room temperature is cooled to about 300 deg. below zero, at which temperature the helium is separated from the resulting liquid-gas mixture; the gas is then brought to room temperature through heat exchangers which cool the incoming gas, and is sent on to the city of Amarillo. This complete operation from room temperature to 300 deg. below zero and back to room temperature takes place, for any given foot of gas, in a total elapsed time of less than a minute. During the process a small amount of nitrogen is also removed from the mixed gases and sent to a gas holder to be used in the refrigeration cycle.



Helium Separation Building, Showing Major Equipment

INITIAL refrigeration and that necessary to make up for some of the heat losses is produced in a separate cycle. The nitrogen which was mentioned

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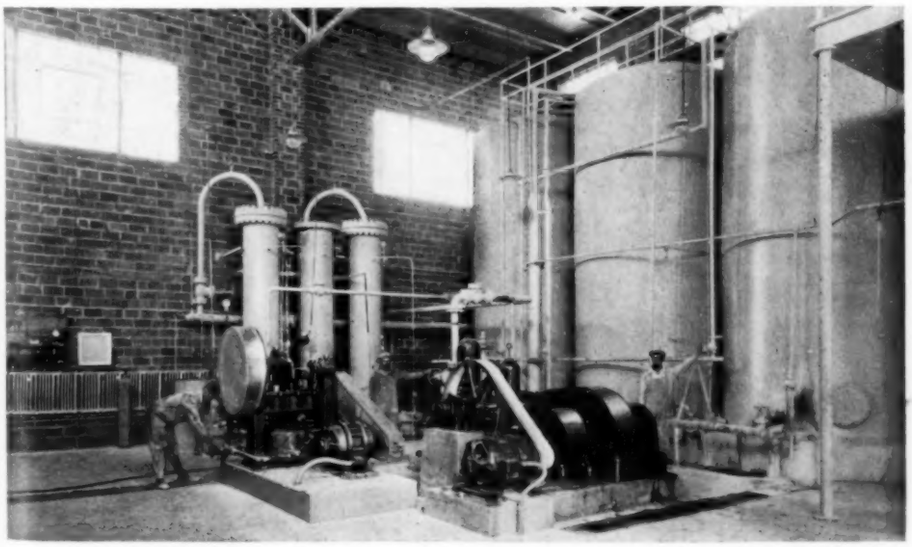
Plant

AT AMARILLO, TEXAS

above is first compressed to about 500 lb. per square inch. After having the heat of compression removed it is expanded through a small expansion engine to atmospheric pressure and returned through heat exchangers to the gas holder. The engine is caused to do work by running an electric generator, thus removing energy from the gas. The cold exhaust is made to cool the nitrogen entering the engine. The system is cooled progressively in this manner until the exhaust of the engine is sufficiently cold for the purpose. This nitrogen refrigeration cycle is kept entirely separate from the natural-gas circulation and is used to make up for a portion of the heat losses in the system and to furnish the necessary low temperature to bring the helium up to the desired purity.

Since considerable cooling is obtainable by throttling the natural gas from 650 lb. to the return gas pressure of about 75 lb., not much refrigeration is needed from the expansion engine after the plant has reached a steady operating condition.

The helium produced as has just been described, has a purity of from 40 to 80 per cent, depending on the method of operation. Helium of a higher purity could be produced in this manner if it were thought advisable. However, an increase in purity, the temperature remaining the same, would call for a higher operating pressure at the point where the helium is removed. This would result in a lower recovery of helium, because of the higher loss through solubility. Also since the helium is all shipped at a pressure of 1,800 to 2,000 lb., it is thought advisable to produce the final product in two steps. Accordingly, the helium which is produced in the first step as just described, is sent to a gas holder and from there recompressed, carefully dried over lump caustic soda, and sent through another similar cycle, by which its purity is stepped up to approximately 98 per cent. Incidentally, this purity has never been maintained by any other helium production plant.



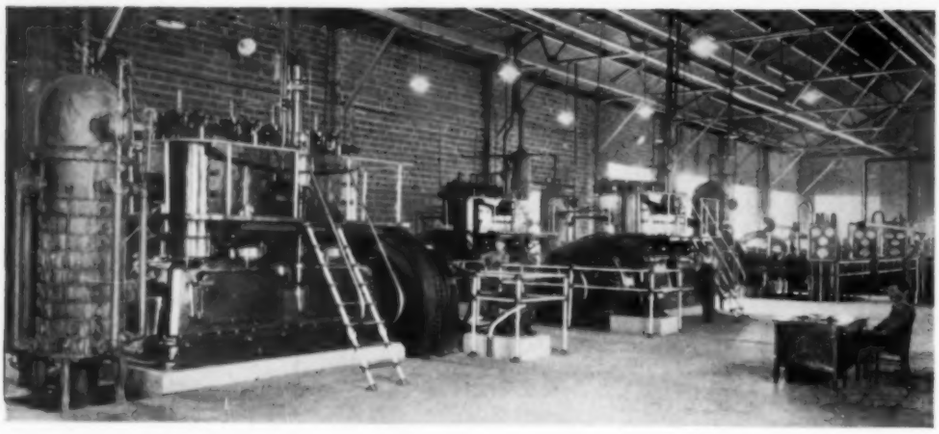
CO_2 Removal, With Caustic Pumps, Separators and Storage

Inasmuch as the purification cycle handles only about 5 per cent of the total quantity of natural gas coming to the plant, it is a rather small affair compared to the cycle for producing the crude helium, and does not require so much refrigeration for its operation. The same expansion engine that furnishes refrigeration to the crude-unit, also furnishes refrigeration to the pure-helium cycle. The latter operates at a pressure of 2,000 lb., per square inch, and the helium which is thus produced is sent directly into tank cars, small cylinders, or storage.

The helium is shipped from the plant to the Army and Navy flying fields either in tank cars or small cylinders. Each of the helium tank cars consists of three or more large heavy-walled, seamless steel tanks mounted on railroad trucks. These tank cars, filled to a pressure of 2,000 lb. per square inch, hold about 200,000 cu.ft. of free gas. The small cylinders, which are shipped under a pressure of 1,800 lb. per square inch, hold about 178 cu.ft. each. It takes about two box cars full of these small containers to equal one of the tank cars in volume of helium.

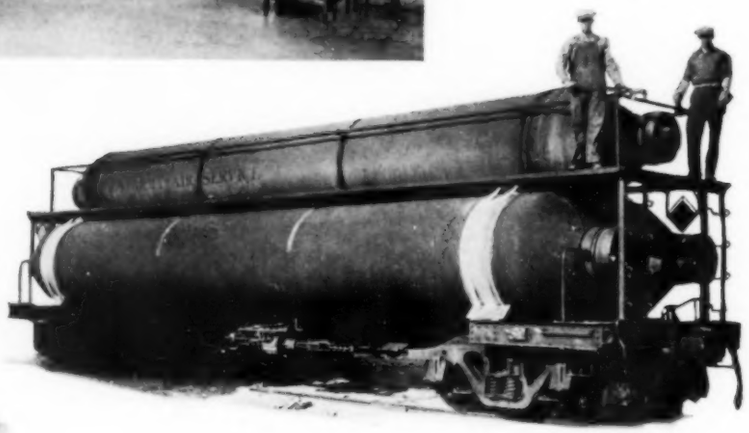
In addition to the small cylinders which are used for shipments, sufficient numbers of such cylinders have been manifolded together in permanent storage to take care of 3,000,000 cu.ft. of helium.

OPERATION of the plant is controlled with the aid of several different types of instruments. Thermocouples are placed in various parts of the unit to give accurate temperature readings. Orifice meters are used for measuring

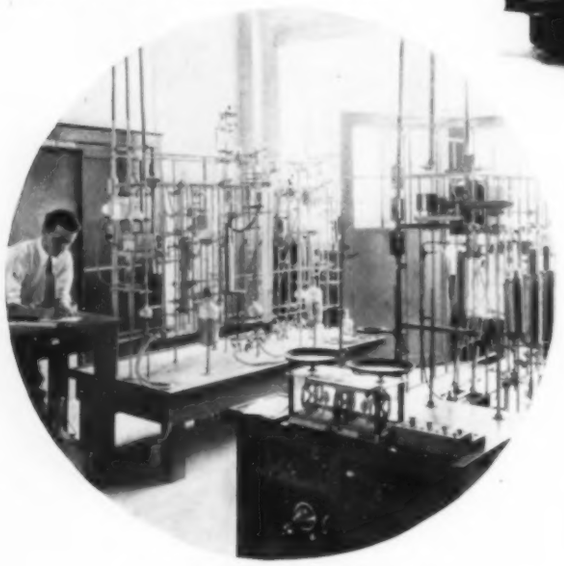


Power House, With Gas Engine Units in Foreground and Compressor Units to the Rear

Specially Designed Steel Car for Helium Under 2,000 Lb. Pressure per Square Inch



gas flows. Differential meters are adapted to indicate the height of liquid in different parts of the unit. Numerous pressure gages are an essential part of the equipment. Perhaps the most indispensable instruments are the automatic helium recorders. These are of the continuous recording type and give the purity of the helium produced during the entire 24-hour period. They are based on developments worked out by the Bureau of Standards and operate on the principle of thermal conductivity.[1]



Cryogenic Laboratory with Gas-Analysis Apparatus

All of the power and compressor equipment is housed in a separate building. Four gas-engine-driven generators of 250 hp. each furnish electricity for power and lighting throughout the plant. The main electrical distribution board is located adjacent to the generators. Gas-engine-driven three-stage compressors furnish the compressed nitrogen for use in the expansion engines. Electrically driven four-stage machines are used to compress the helium to 2,000 lb. per square inch. In the power house are also located the circulating pumps connected with the spray pond and the cooling water system of the compressors and gas engines. Boilers heated by the exhaust from gas engines, and a gas-fired boiler installed in a separate room in one corner of the compressor building, furnishes steam for the entire plant. The unit heating system is of the vacuum-return type. A small, centrally located building houses a modern change room. The basket system is used.

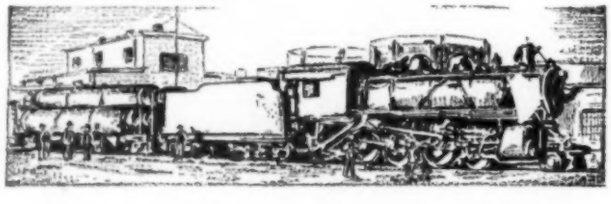
Since all repairs to plant equipment must be made on the job very complete workshops and a storeroom have been installed. These are located in a separate building. Besides having the ordinary tool equipment found in most small shops, it has been necessary to install a boring mill, planer, gap lathe, etc. With these shop facilities a second unit of the plant was recently completed, all major parts of which were fabricated by the government's own mechanics. This equipment is more efficient and is standing up better than the first unit, the parts of which were built largely under contract.

A garage building houses the government transportation equipment. The gasoline-engine-driven fire pump and auxiliary lighting equipment of the battery type are located in a fireproof section of the garage.

The cryogenic laboratory occupies a building of its own on the plant. This laboratory houses the research equipment used on general gas problems, most of which involve low temperatures. The research staff consists at present of five men. In addition to these the plant has two chemists who take care of the plant control work.

BUILDINGS throughout the plant are of a permanent type. In general they are constructed of hollow tile, with steel frames. The roofs are either corrugated sheet asbestos or flat deck, 20-year, built-up roofing. As a matter of fire protection, separate buildings were erected to take care of the various operations. These are grouped in such a way that plant efficiency is not impaired.

As an indication of the overall plant efficiency, it might be said that the net operating cost per thousand cubic feet of helium produced at Amarillo in June, 1930, was only about one-quarter of the lowest cost over a month's operation ever made at the old Fort Worth plant.



[1] P. E. Palmer and E. R. Weaver; Tech. Paper Bureau of Standards, No. 249.

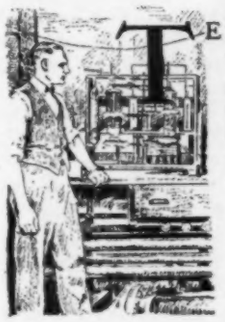
Developing New Markets For Products of

High-Pressure Synthesis

By C. L. BURDICK

Assistant Chemical Director, DuPont Ammonia Corporation, Wilmington, Del.

HERE Dr. Burdick sets forth some of the factors affecting the growth of what may be termed the newest chemical industry—high pressure synthesis. He has considered some of the problems, the tools and methods that may be used, and some of the results already achieved.



TECHNOLOGY which has had a phenomenally rapid development has brought forcibly to the attention of the high pressure synthetic industries the necessity for expanded markets for its products. The whole of the chemical industry during the last decade has been moving forward at an ever accelerating pace. In no other period has there occurred such a rapid increase in output of chemical products. Even the Solvay ammonia-soda process, one of the most stabilized and fully developed of our chemical industries, has shown a greater increase in this period than for the previous two decades of the century and this is only one of many examples that might be cited.

There is no doubt but that one of the major factors in this movement or development has been the application of intensive methods of scientific and technical research to industrial processes. This relates by no means only to chemical and chemical engineering research but involves just as intensive an application of the methods of physical, mechanical, or biological research. In general we have concentrated on production research—new ways of doing things. Production methods have been improved along all lines and we have cheapened costs to undreamed-of levels. As a result, prices of basic chemical commodities are now around the lowest figures for all time.

An upsetting influence is caused by the entry of a new factor, such as the high-pressure synthetic industry, in the chemical or industrial world. New products equal or superior to those now in established use are coming on the market. By intensive and large-scale methods of manufacture they are produced at cost levels which permit effective competition. There is the obvious danger here of a situation arising which is quite similar to that termed "technological unemployment," the displacement or abandonment of good, useful, trained, or well-established human material, because someone has discovered other and more efficient ways of doing things. Just as this technological unemployment provokes new competition and the lowering of standards under which men work, so this tendency toward industrial replacement of commodities with similar or equivalent products works toward the same thing—that is, a keenly competitive situation and lowered prices.

THE ALTERNATIVE to this situation is plain. With the development of these high-pressure synthetic products it is essential to find new outlets and new uses for them. This is an opportunity as well as a responsibility and it should be approached from this combination point of view. The high-pressure synthetic manufacturing industry should acquaint the consuming industries with what is being accomplished in the high-pressure field and likewise should help these industries in applying the results of the research in this field. From another and perhaps more strictly utilitarian or selfish point of view it is essential for the high-pressure industry to go a long way in aiding in the application of its products.

RECENTLY new capital has been invested in chemical industry and is still being invested at an unprecedented rate. Present capital investments are being depreciated just as fast as established processes or products become obsolete. High-pressure synthetic plants and equipment are exceedingly expensive and it is foolish to assume that they do not fall in the same general category. Therefore, in the short space of time that elapses between the construction and the scrapping of a plant every effort must be made to secure the greatest productivity and utility of the invested capital. A major way to do this is to help in the utilization in industry of the products which the plant makes.

As Dr. W. S. Landis has pointed out, one will find that out of every ten men engaged in research work in our important industrial organizations, eight are studying improvements of methods or new processes and scarcely two will be found to be working on methods of utilization—helping in a fundamental way to find markets and uses for materials or products already or prospectively in hand. It is questionable whether this is not misplaced emphasis for the best commercial results and the adequate financial safeguarding of a corporation's fixed investments. To

make certain that one is to get one's money out of a given project before venturing into new commitments may be homely philosophy, but it keeps corporations out of the hands of bankers and reorganization committees.

In several of the basic industries production has greatly outstripped consuming capacity. The sugar industry has made great technical advances, but in general the industry is in a sorry plight. The fertilizer industry has a productive capacity largely exceeding any apparent possible consumer demand. The nitrogen industry is in a not too invulnerable position, as is witnessed by the recent European agreement among the major world producers whereby production quotas for all are written down so low that it is problematical whether they can make more than meager profits on their relatively large capital commitments.

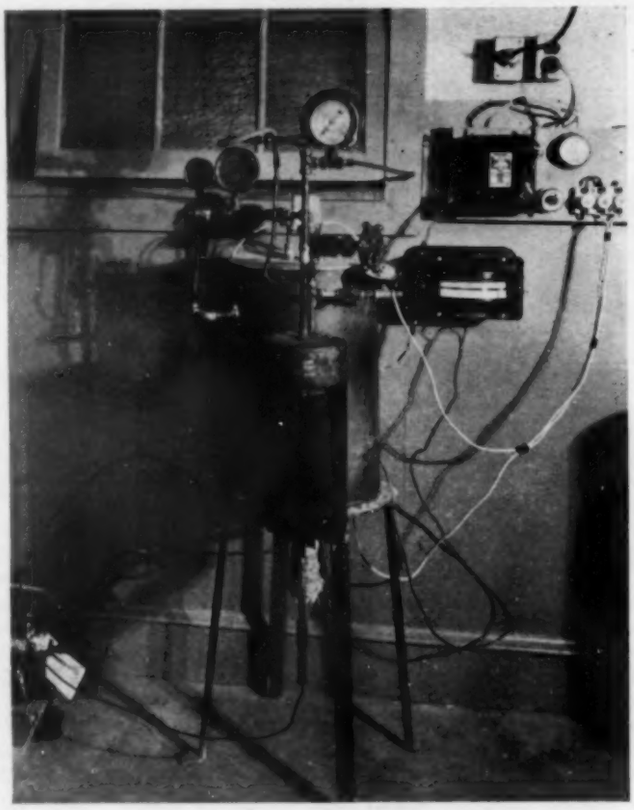
For such an industry, the only remedy is to find new outlets and new uses for its products, so that production can be brought proportionately into line. As the newest participant in the large-scale manufacture of chemical products, the high-pressure synthetic industry should try to maintain a sound position with a proper distribution of effort between production research and product-utilization research.

General aspects of product-utilization research have something in common with the medical profession. When a new medicine is discovered it is tested adequately under careful controls before committing it on an innocent or unsuspecting public. Not to do so savors of charlatanism. Introducing new products into industry runs the same risks. Ethics are as essential in this field as in the medical field.

There is another aspect of product-utilization research which is similar to medicine. Both require outside subjects for their activities. The doctor, utilizing the recent discoveries of the hospitals and laboratories, works out a new technique of treatment in his contacts with his patients. With good luck they benefit and he benefits. The product-utilization research group has to acquire contacts with industry to work out jointly with the men in industry how the particular products or technique in the group's hands can be applied. The doctor in a way can make no headway unless patients come to him. The utilization research group likewise must establish contacts in order to secure the opportunity to prescribe or offer suggestions.

Fortunately, the analogy drawn above stops short of the somewhat fearsome term, "medical etiquette." Except for violations of confidence, the utilization research group has no inhibitions against publicity for any good results attained. Publicity for technical advances is legitimate, providing the approach is conscientious, straightforward and honest. "Telling the world" of the excellence of new synthetic products, as evidenced by successful new applications, is part of the duty of a new technical enterprise. It ought to have enough of the missionary spirit to believe in preaching the gospel in far fields; to believe that what seems good in one field of application cannot help but yield bounteous satisfaction to others not yet enlightened.

The tools or the methods at hand for the product-utilization work divide into several groupings. Pure and applied research serves to establish the properties of the new chemicals, to indicate the fields wherein applications for them may be expected, to investigate the industrial and health hazards, and so on. In this field of work we find co-operation with the various government bureaus and exchange of scientific information with men in research and educational institutions to be valuable adjuncts and aids in arriving at an unprejudiced viewpoint and getting at the real facts of a problem.



This Experimental Ammonia Dissociator or "Cracker" Was Developed by the Sales Research Staff of Du Pont Ammonia Corporation

Field service involves, on the first hand, intimacy of contact with the industries in which applications are thought to be possible. It involves a candid exchange of engineering and chemical ideas, and consultation and advice between the technical groups concerned. Discussions may often be initiated to good advantage between purchasing agents and salesmen, but the most rapid progress in fundamentals is achieved by direct contacts between the technical men concerned.

The second category of work in this field is sales engineering or sales service as integrated with the work of the regular sales department. Many ideas as to new applications come from discussions involving the sales-service people and the men with whom they are contacting in the industry.

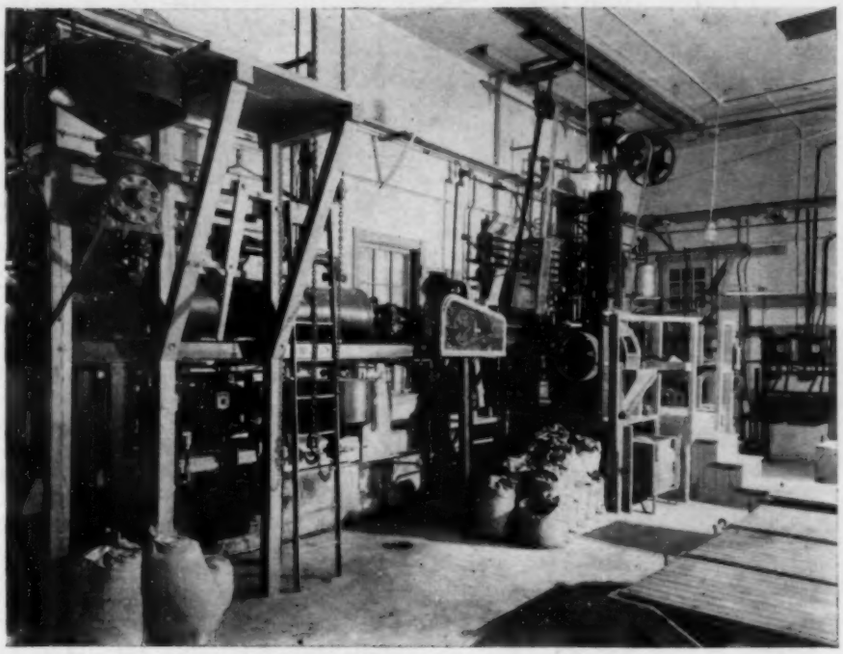
A third category under this heading is attendance at scientific meetings and conventions. The informal discussions that take place among technical men under such circumstances are fertile sources of suggestions of new applications and new uses for products.

Avenues opened by publicity are: (1) Paid commercial advertising. (2) Indirect publicity through news items relating to new developments of general interest. (3) Technical articles. (4) Selected circulation of descriptive material, leaflets, reprints, and so on.

The above principles can be made more tangible through concrete examples. Therefore some of the features of this sort of work as carried out by the Du Pont Ammonia Corporation may properly be mentioned.

In so far as concerns the truly technical aspects of the above activities they are being carried on within this company by or with the advice of its chemical department. A generous proportion of the budget of the chemical department is allotted to research work in these fields of product utilization. Naturally, a reasonable part of it goes to take care of day-to-day problems and service, but likewise the fundamental and long-range aspects of our problems receive as much attention as possible.

It is constantly necessary to control carefully the distribution of expenditures in the various fields. Interesting possible new uses for our products are constantly coming along and it is tempting to spend money to follow them up. As technical or research problems they may be attractive, but as a practical matter, expenditures must arbitrarily be proportioned to the prospective magnitude of



Part of the Equipment in Du Pont Ammonia Corporation's Complete Fertilizer Research Laboratory and Experimental Plant

the business. Sometimes errors of judgment occur. In at least one case a laboratory development that we considered practically concluded and that looked like only a relatively minor future use for ammonia developed side possibilities in its technical applications that increased this particular outlet many fold.

Marketing in a retail way ("package business") is extremely costly and research to encourage minor applications is equally expensive. The unit-sales expense for ammonia marketed in cylinders is more than 20 times the corresponding expense for marketing in tank-car quantities, in spite of the fact that the business is done on the closest possible margin which will yet give satisfactory service to the consumer. Service-engineering or sales-research budgets should stand in no direct relation to sales expense. The major research work should be directed toward the markets with large prospective tonnage where selling expenses are low.

INCREASED OUTLETS and uses for synthetic ammonia fall into two categories: old or well-known uses that have expanded because of the great drop in price that has accompanied the introduction of synthetic ammonia into the market; and second, actual new uses developed only because of the wholesale availability of this new cheap heavy chemical.

The present annual consumption of nitrogen compounds in this country for other than fertilizer purposes is roughly equivalent to 124,000 short tons of nitrogen. Approximately 17 per cent of this goes into explosives, 51 per cent into chemicals and acids, 12 per cent into refrigeration, and 20 per cent into miscellaneous industries.

In the explosives industry nitrogen already plays a vital part, and growth in nitrogen demand will come chiefly through growth of the industry. Change will come in form rather than in quantity, probably through replacement of natural nitrates with products from synthetic sources.

Refrigeration is a market of steady and sound growth. The cheapening of synthetic ammonia and the nuisance and expense of maintenance of brine-cooling systems will probably bring about the wide adoption in refrigerating practice of circulating systems using ammonia vapor directly instead of the old-style brine systems. The ammonia-vapor system is simple and is not subject to deterioration. It does not consume ammonia, but it takes a larger stock of ammonia to fill the system, and in that sense it is an outlet for ammonia.

Percentage-wise the largest industrial outlet for ammonia is in the field of chemicals and acids. The most important outlet in this field is nitric acid and nitrate derivatives, such as ammonium nitrate and various nitrocellulose products. Ammonium nitrate, while classifying really as an ingredient of explosives, has numerous other applications. Judging by German and British experience, there is also prospect of it becoming an important fertilizer material. In an interesting new application in this field ammonium nitrate is prepared as an intimately incorporated mixture with calcium carbonate or ground limestone.

Progress with these nitrate derivatives, particularly those of a cheaper order, has been retarded by the relatively high cost of oxidation or conversion of ammonia to nitric acid. The Du Pont company, as one of the major users of nitric acid in the country, has concentrated a great deal of research effort on this problem. Much has been accomplished and today the rate of nitric-acid output per unit of capital invested has been increased threefold as compared with the situation of two years ago. Not only this but the conversion efficiency has been steadily stepped up until now the margin of possible improvement has become a minor item in affecting costs. As a result of this development many Du Pont pressure-oxidation plants are being constructed, not only in the United States but also in Europe and Russia. These all mean increased outlets of ammonia for some producer.

In this connection it is worthy of note that we have found that synthetic ammonia from all sources is not alike in efficiencies and performance obtainable in ammonia-oxidation plants. As far as is known, all synthetic ammonia plants are turning out a product eminently satisfactory for ordinary chemical purposes. However, where the ammonia is to serve as a raw material for a subsequent catalytic process, its source and the minor impurities contained should be considered with some care. The impurities apparently arise in the method of ammonia synthesis that is used.

IN THE CLAUDE synthesis the gases are compressed once to a high pressure and follow then through a succession of synthesis tubes between each series of which are coolers for the condensation of the ammonia as liquid. The unconverted gases emerging from the last tube are purged from the system. In the other standard processes the purge gases are recompressed, then usually scrubbed with the freshly formed ammonia coming from the condensers, and the gases are returned to the process. This scrubbing is for the purpose of removing broken-down oil from the compressors or any other constituent of the gas which might affect adversely—that is, "poison"—the ammonia catalyst. Unless redistilled before being shipped to market, this ammonia naturally contains these constituents which are equally harmful to the catalyst in the ammonia-oxidation plant. Appreciation of factors like these, involving fractions of a part per million, is achieved only by painstaking research and close control of operating technique. However, the widespread application of a new industrial product may be seriously retarded by failure to take such factors into account or through one inferior product stigmatizing the product of a whole industry.

Of the various miscellaneous new uses for ammonia that could serve by way of illustration, may be mentioned the purification of water supplies by the combination treatment with chlorine and ammonia (chloramine), the use of ammonia as a substitute for lime in the manufacture of sulphite pulp, the use of ammonia gas as an accelerator in

rubber vulcanization, the process of cracking ammonia to give a cheap source of nitrogen or hydrogen, ammonia as an alkali (it is cheaper than caustic soda per unit of neutralizing power), and the direct absorption of ammonia in mixed fertilizers. Ammonia is an interesting chemical from the utilization point of view because of its numerous reactive properties; for example, as an alkali, as a fuel or reducing agent, as a source of nitric acid, and as a nitrogen compound and source of organic nitrogen derivatives.

The combination use of ammonia and chlorine for water treatment is growing rapidly. Apparently this combination constitutes not only an ideal sterilizing agent for potable water but it is showing possibilities of wide industrial application. As a disinfectant for sewage and as an inhibitor of algae growth, not only in swimming pools but also in the condenser water in power systems, it is making headway. In the latter case, apparently, the slime-coating of the cooling water surfaces is largely prevented and surface condensers are found to operate at improved efficiency for longer periods of time between shutdowns for cleaning. Chloramine also has possibilities in the preliminary treatment of woodpulp for rayon manufacture. A strong bleach, such as chlorine, may work injury, as compared with the mild, controllable action of chloramine.

CHLORAMINE is a good example of an aspect of product-utilization research. Starting with a comparatively simple idea, the development has grown largely through the appreciation by others of its advantages for their purposes. Generally speaking, all that has been necessary is to bring its properties to the attention of active-minded technical people with problems of their own to solve. They have done the rest. This was accomplished largely through the private publication and circulation of a pamphlet embodying a critical scientific review of all known experimental work and facts relating to chloramine, including whatever thoughts we had or studies we had made as to its possible industrial utilization.

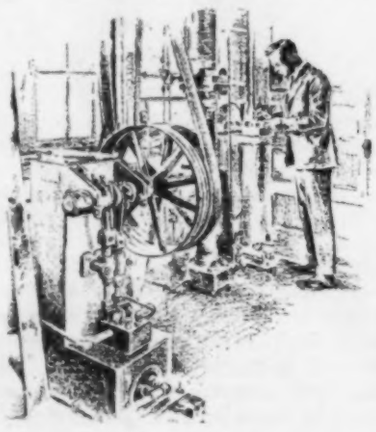
Miscellaneous new applications for ammonia have sprung up with each fractional lowering of its price. An example of an old or known but hitherto unprofitable use of ammonia which has suddenly taken on an important commercial significance due to cheap synthetic ammonia is the so-called "ammoniation" of superphosphate in mixed fertilizers. The treatment of the superphosphate or "acid phosphate" of the fertilizer trade with ammonia to neutralize the excess acidity of the product, simultaneously thereby fixing ammonia and improving the physical condition of the fertilizer, was proposed back as far as 1871. Three years ago the process came into its own commercially when prices came into line and when research and commercial trials showed that this process constituted the best known means of improving or "conditioning" the physical properties of mixed fertilizers. The result has been the displacement of a large tonnage of organic ammoniates and other types of conditioning agents. Now around 50,000 tons of ammonia per year is being marketed in this way. This development has been described by R. S. McBride (*Chem. & Met.* vol. 36, p. 592, 1929).

THIS ARTICLE would be incomplete without mention of some of the problems that are before us in connection with the disposal of other high-pressure synthetic commodities now available on the market—namely, the synthetic alcohols. The output of several of these synthetic products is limited because of inability or lack of knowledge as to how to dispose of them. The methods and the circumstances, of course, vary.

In some cases entirely new products are concerned which hitherto have not even appeared in the commercial market. One example is normal propanol, a product produced in quantity as a byproduct of synthetic methanol manufacture and for which no uses have as yet been found. Other examples include hexyl, heptyl, and octyl primary alcohols, as well as numerous higher secondary alcohols. If markets develop, catalytic procedures or high-pressure technique can doubtless be altered to permit the production of larger quantities of these products.

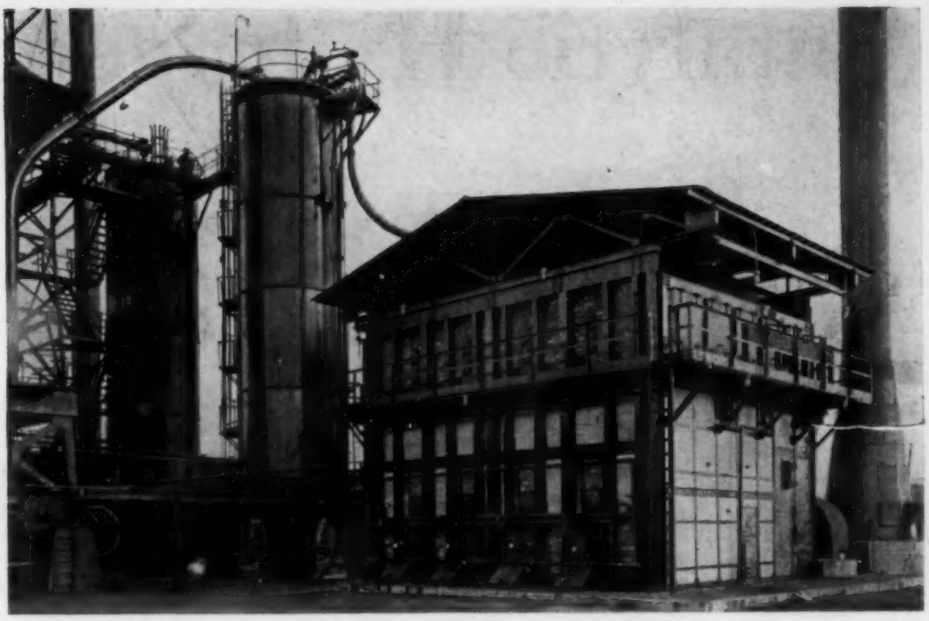
Another example of a somewhat different sort is the prospective use of synthetic methanol as an anti-freeze for automobile radiators. Methanol has been used for years for this purpose in the wood-distilling districts in Wisconsin. Control tests of methanol anti-freeze were carried through last year on a large scale, but this application has never really been on a commercial basis until this present season when the price of synthetic methanol dropped to levels that permit equal freezing protection at lower cost than with any other organic anti-freeze agent.

The interesting corollary of the methanol anti-freeze application is the recent discussion that has taken place in the technical press as to the possible toxic effect of methanol in this application. Considerable propaganda from various sources has been made against its use. Methanol, however, is in a strong position. Based on a background of experimental evidence and practical tests, prominent public-health investigators have expressed the judgment that the normal use of methanol as an anti-freeze in the automotive field constitutes no more of a toxicity hazard than does gasoline under ordinary conditions of its use. From a practical point of view, any garage condition that takes care of carbon monoxide from motor exhausts effectively prevents any possibility of injurious concentration of methanol vapor.



To obtain a final and incontrovertible opinion on this subject, and appreciating that because of its cheapness methanol is inevitably going to be used unless something more powerful than propaganda is directed against it, the methanol producers inaugurated some time ago a series of tests under the direction and control of the Pittsburgh station of the U. S. Bureau of Mines. This organization is proceeding to establish whether methanol is in any way dangerous when used as an anti-freeze. These results, soon to be forthcoming, will either give methanol a clean bill of health for this purpose or the methanol producers will join in warning the public against its use in this field. On the other hand, if the methanol tests turn out satisfactorily, the aftermath of the propaganda, which has already served as an effective means of calling the attention of the trade to the technical excellence of methanol as an anti-freeze, may result in an entirely unexpected demand for the product.

THERE is one general principle of product-utilization research that should be mentioned: namely, the necessity of the maintenance of a point of view that the results and advantages from the research must pass on to the customer or consumer. The policy has to be established and adhered to that the producer must give up the thought of capitalizing directly the results of his own investigations in the field. It is for the benefit of the consumer. This is not an altruistic thought; it is a hard and unavoidable fact. Since utilization research means intimate contact with consumers in working on their problems, it involves therefore a confidential relationship. Results of the research are passed on to the consumer. In certain cases they can be made generally available to the industry. The only return that the producer and sponsor of the utilization research can get is at best a generous share of the increased market of the commodity in question.



Dubbs Unit Employs Tubular Furnace as Is Shown Below

Mounting Pressures and Temperatures in Cracking Petroleum

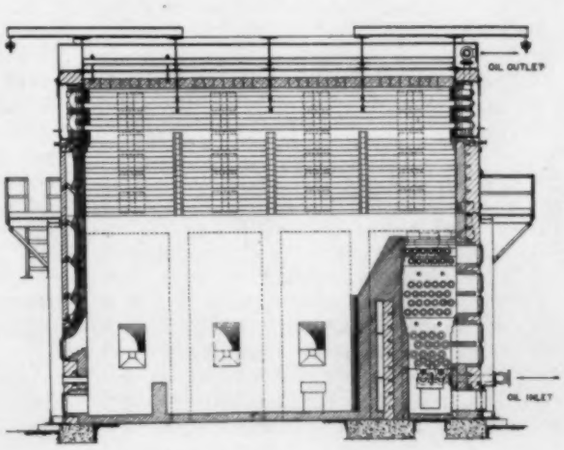
By JOHN S. WALLIS

Oil Department,
Foster Wheeler Corporation
New York, N. Y.

PRESSURE-TEMPERATURE relations have played important rôles in petroleum refining since the time when Dr. Wm. M. Burton and his associates built the first commercial pressure still. This was a cylindrical shell 8 ft. in diameter, 20 ft. long, built of ½-in. mild steel plates and holding 6,000 gal. of charging stock. It had a safety factor of 5, for the working pressure was 100 lb. and the bursting pressure 500 lb. Its operating temperature was around 700 deg. F. Today the modern tube still has practically replaced the older type of shell still in all pressure operations and the demand for lower operating costs combined with more rigid gasoline specifications has required increasingly high temperatures and pressures.

Most of the well-known commercial cracking processes now operate at pressures from 400 to 700 lb. at the tube still outlet and temperatures range from 700 to 900 deg. F. Quite recently operating conditions of approximately 1,000 deg. F. and 1,000 lb. pressure have been found to yield satisfactory results. Further investigations have created a demand for even higher temperatures and pressures, with the result that plants now under construction are being designed for still outlet temperatures in excess of 1,000 deg. F. Furthermore, hydrogenation at extremely high pressures with temperatures sufficient to carry on the required chemical reactions may bring about a complete revision of present-day methods for converting the heavier derivatives of petroleum into more volatile fractions. Numerous other developments, such as the vapor-phase cracking units, may indicate that high temperatures and low pressures are often desirable.

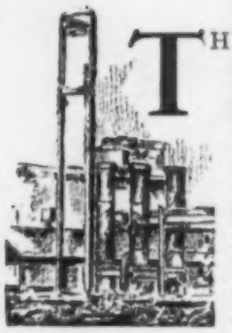
It is generally accepted that tubular heating is most readily adapted to the high-temperature, high-pressure demands of the petroleum industry. Speaking broadly, the still design for a modern oil-cracking unit consists of an arrangement of tubes in a radiant heat section and in a convection section such as is shown below. This type of furnace has been built by various companies with modifications and auxiliary apparatus, such as flue-gas recirculation and air heaters. The general type follows the same principles of design, with each plant modified to meet requirements.



It is also of interest to chemical engineers to observe that tubular heaters of comparable design have been successfully used in other high-temperature and pressure applications. For example, in certain nitrogen-fixation processes the gases are heated to temperatures of 900 to 1,000 deg. F. at pressures up to 5,000 lb. Steam superheaters in certain process industries operate at 150 lb. pressure, producing final steam temperatures of 1,250 deg. F. In short, while the petroleum industry has developed equipment and technique for high temperatures and pressures, it is apparent that these are equally applicable in other fields where comparable severe service requirements must be met.

What Catalytic Hydrogenation

By S. D. KIRKPATRICK
Editor, Chem. & Met.



THE NEWEST and potentially most important development in pressure application in industry is now in operation at Bayway, N. J. The Standard Oil Company of New Jersey has completed and is operating a 5,000-barrel-per-day hydrogenation plant treating petroleum by a new process.

After intensive laboratory work and engineering research starting in 1927 at Baton Rouge, La., and the construction of a small experimental plant there, the process is now reported to have reached commercial fruition. Construction of the plant at Bayway was started late last year, and the first unit placed in operation in August, 1930.

Underlying this new development is a vast amount of experimental work and painstaking research. As far back as 1899, Sabatier and Senderens demonstrated the feasibility of reducing unsaturated gaseous hydrocarbons by means of hydrogen. These workers and many others over a period of years dealt with oils, fats, and other organic compounds, culminating with the brilliant work of Friedrich Bergius on coal hydrogenation. The I.G. Farbenindustrie A.G. took up the work as a logical outgrowth of their experience in developing the Haber process for nitrogen fixation and the synthesis of methanol from water gas. The application of high-pressure technique and experience to new fields was indeed an expected development. The work of the I.G. resulted in the erection and operation of a coal hydrogenation plant at Leuna, near Merseburg, which in 1928 produced 300,000 bbl. of gasoline from coal.

A review of the published work on hydrogenation shows a wide variety of possibilities. Reactions indicating the direct addition of hydrogen to a hydrocarbon molecule, reactions by which dissociation or cracking occurs after hydrogen addition, simple dissociation and formation of new hydrocarbon molecules by recombination of cracked fragments, and also by hydrogenation of the cracked fragments themselves, are known. Chemists have been able, therefore, to establish the mechanism of many different kinds of hydrogenating reactions. The type of reaction occurring in a given case is dependent upon the conditions of temperature, pressure, time, and the character of the catalyst present. Practically all of these reactions are favorably influenced by pressure, since a volume decrease is involved. Temperature, however, is a much more important factor in determining the nature of the reaction. It has been shown that certain catalysts can cause hydrogen to combine with many organic molecules at normal or high pressure; but as far as molecular hydrogen is concerned, pressure alone is insufficient. Generally speaking, hydrogenation involves the rupture of molecular groupings by means of elevated temperature, and the subsequent reaction of hydrogen with these ruptured groups, to produce, in general, lower weight hydrocarbons. The recombination of ruptured groups with others can likewise produce new combinations having different properties. A balance between the rate of thermal dissociation and the rate of reduction by hydrogen determines the yield and character of the products. Research consists in determining the conditions under which the desired balance between cracking and hydrogenation exists.

THERMODYNAMIC stability of simple, aliphatic hydrocarbons is less at high temperature than that of aromatic compounds and naphthenes. Considering a mixture of such compounds, as the temperature is raised, the aliphatic compounds are the first to crack and disappear from the product, conferring a more aromatic nature on it. The use of lower temperatures under similar conditions results in the formation of a more paraffinic product. The presence of catalysts, of course, alters the rates of reaction in a manner that can be determined only by experiment. The choice of catalysts can, therefore, influence the character of the product. This fact contributes considerably to the flexibility of the hydrogenation process. The production, at will, of a wide variety of gasolines, oils, etc., having either paraffinic, aromatic, or blended characteristics, is an achievement of revolutionary importance to the oil industry. The adjustment of the output of a refinery to varying market demands is an accomplishment that should go far to solve the more important economic problems of the oil industry.

Present cracking processes yield non-condensible gas, gasoline, light oils, heavy oils, and coke. The hydrogenation process reduces gas formation, eliminates coke entirely, and converts the heavier fractions into suitable motor fuel or light fractions. One hundred barrels of petroleum can yield 100 barrels of high-grade motor fuel. During the past few years the quality of

Offers

The Oil Industry

New 5,000-Bbl. Per Day Petroleum Hydrogenation Plant at Bayway, N. J.

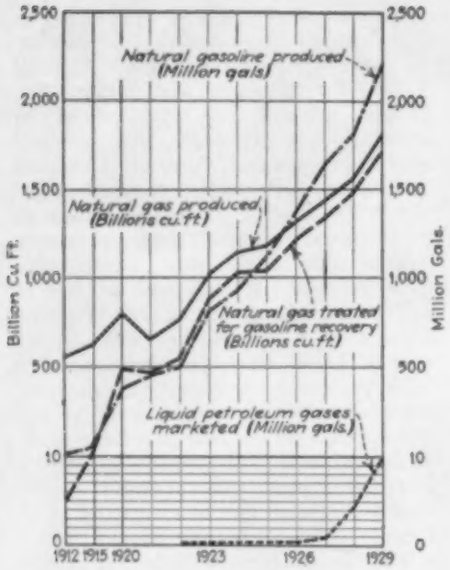
crude oil which has been available to the petroleum industry has changed materially. High-quality oils with low sulphur content are now rare. Today many of the crude oils are of high sulphur content and suitable largely for the production of fuel oils and a minimum of natural white products. As a result of this, and in consequence of the ever-increasing demand for gasoline, it has been necessary to process an amount of crude oil considerably in excess of the economic market demand for the heavy fuel-oil fractions. The utilization of hydrogenation methods promises to relieve the oil industry of this essential burden.

OFFICIAL data and engineering details of the new hydrogenation process are not yet available. Information based on patents covering hydrogenation processes reveals that the preliminary step usually involves the heating of crude petroleum to a temperature of approximately eight or nine hundred deg. F., at which temperature it is discharged into the reactor and intimately mixed with hydrogen under pressure in the presence of finely divided catalysts. The reactions take place, the vapors passing out of the reactor through heat exchangers and condensers, the heavy condensate being recirculated though the hydrogenation process. Gasoline and light fractions are drawn off from the coolers, excess hydrogen and other gases pass through purifying towers and then back into the system. Briefly, the process seems to consist of a circulating oil system into which hydrogen and catalysts are injected, a distillation involving the separation of the light fractions and gas, and a returning of the heavier and unreacted portions to the system. It is known that this process can handle high-sulphur crudes or heavy fractions from ordinary cracking operations without the need of previous purification and that the original sulphur in the oil passes out with the non-condensible gas in the form of hydrogen sulphide. As previously discussed, the nature of the reactions and of the product is determined by the variables, time, temperature, pressure and catalytic agents.

The interest and activity of many companies in the field of hydrogenation is evidenced by a considerable number of patents on the subject. A wide variety of pressure and temperature ranges as well as specifications of catalysts are covered. An unusual patent granted the Imperial Chemical Industries, E.P. 309239, May 29, 1929, covers the destructive hydrogenation of carbonaceous materials under pressures greater than 1,000 atm. Preliminary hydrogenation is performed at 200 to 1,000 atm., the products thus obtained being treated at 4,000 to 5,000 atm. or even at 10,000 atm. The significance of such pressures, of course, is questionable, but when one considers the almost unbelievable strides that have been made in the application of pressure during the last five years, one hesitates to be skeptical about any pressure developments.

Patented features include methods of controlling the temperature of the reacting materials by preheating the hydrogen and utilizing the heat of reaction in the separation of the light products. English Patent 308297, granted the Standard Oil Development Company, states that white oils and other highly purified petroleum oils are obtained by subjecting a crude petroleum or a heavy fraction to hydrogenation and cracking by treatment with hydrogen at a high temperature and pressure, separating and purifying the product. For example, Pennsylvania crude oil is treated at 750 to 850 deg. F. and 550 to 1,000 atm. Preferably the oil is agitated by continuous injection of hydrogen. The process may be continuous or by batches in a reactor having non-reactive steel alloy surfaces. Metal oxides or other catalysts, such as a mixture of 9 lb. of chromium oxide with 1 lb. of molybdenum oxide, are suspended in the oil during hydrogenation.

SUCCESS of large-scale oil hydrogenation projects is contingent upon the solution of many new problems—chemical, metallurgical, and engineering. High temperatures and pressures coupled with the corrosive properties of sulphur-bearing oils, the flammability of hydrogen and its ability to diffuse through metals as well as to decarburize and weaken steels combine to make the large-scale operation of this process exceptionally difficult. Millions of dollars spent in research and development coupled with the best chemical engineering abilities and manpower available to large corporations have brought the development to commercial status. For the first time the refining industry has available a process for the constructive upbuilding of its products without a corresponding degradation of a portion thereof. It probably is true that the adoption of catalytic hydrogenation methods by the oil industry, even on a small scale, will cause a definite overlapping with the more strictly chemical industries.

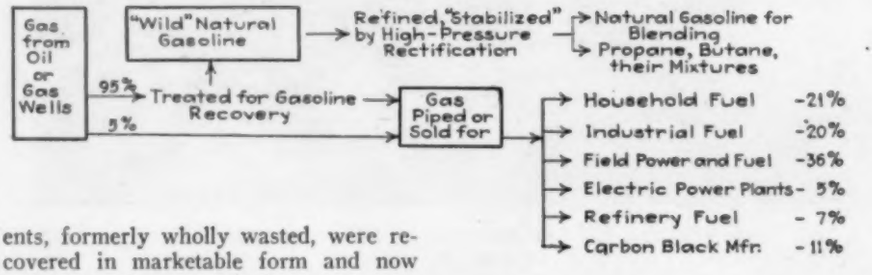


Trends in Natural Gas Industry, Showing Increased Emphasis on High-Pressure Treatment

New Fuel Industry

Created by

High-Pressure Technology

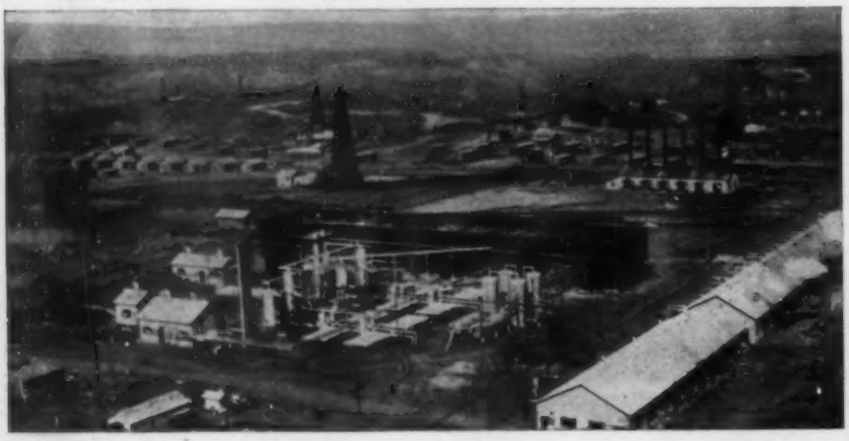


STABILIZATION of natural gasoline by high-pressure rectification and recovery of the highly volatile constituents represents one of the outstanding chemical engineering achievements of economic importance to the petroleum industry. Formerly, recovery of natural gasoline, "casinghead gas," as it was called, was practiced with fair efficiency as far as gaining control of the group of light paraffin hydrocarbons from propane to hexane and heptane. But the preparation of these mixtures for market was an extravagantly wasteful operation, often a mere weathering in open tanks, with incomplete evaporation to the air of the unwanted light constituents and grossly wasteful vaporization of the desirable heavier members of the group.

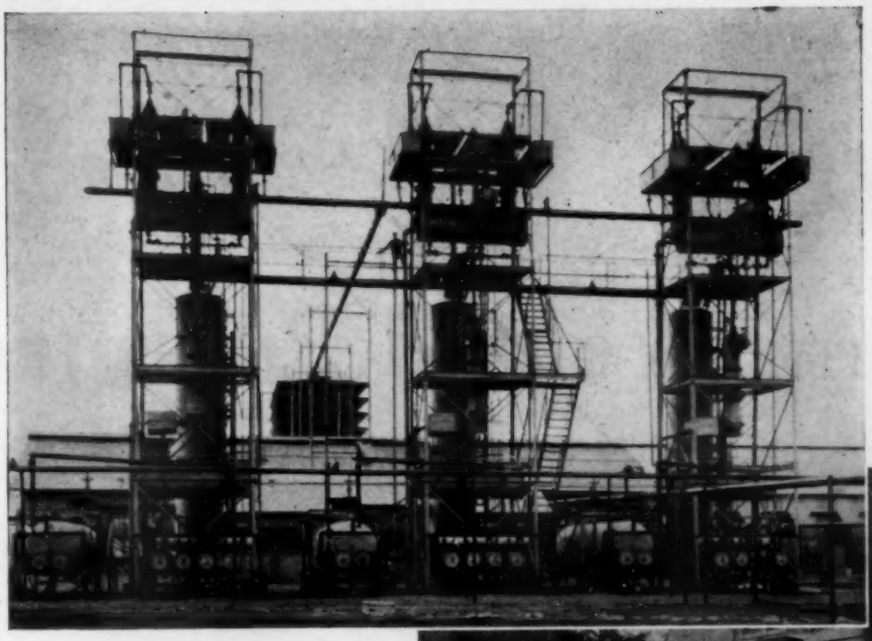
That technology which had made rectification of liquid air under high pressure a commercial success was adapted to this task and "stabilization" became an economic thing. The important results were twofold. A vastly improved natural gasoline was provided for blending purposes, with greatly increased yields; and the light constituents, formerly wholly wasted, were recovered in marketable form and now constitute an extremely important new element in our liquid and gaseous fuel supply.

With the availability of propane and butane and their mixtures in huge quantities came the necessity for developing transportation and utilization facilities of new types. The chemical engineers connected with this division of the petroleum industry have had outstanding success in both efforts. The propane car became the pioneer of high-pressure liquefied-gas units satisfactory for flammable materials of this sort. And the development of retail pressure storage and handling facilities, including household and industrial utilization equipment, makes practicable the efficient use of this gaseous energy in quantities that exceed the total energy annually available at present from all coal-gas, oil-gas, water-gas, and coke-oven-gas establishments of the United States.

Thus has high-pressure chemical-engineering technology, as adapted to the needs of the petroleum and natural-gas industry, incidentally created a third division of that fuels group, a "liquefied petroleum gases" industry. This business already markets annually more than 10,000,000 gal. of these new products.

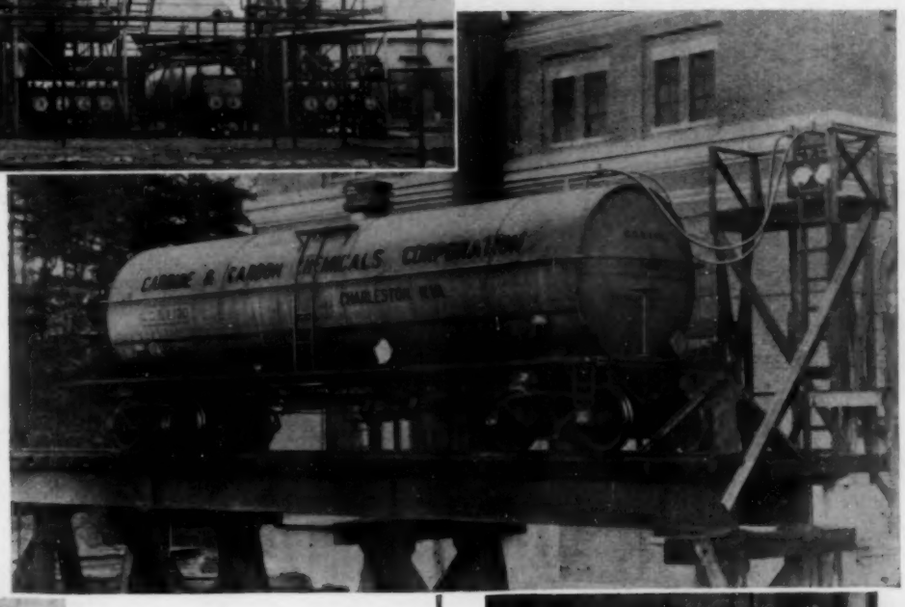


Plant for Extraction and Rectification of Natural Gasoline



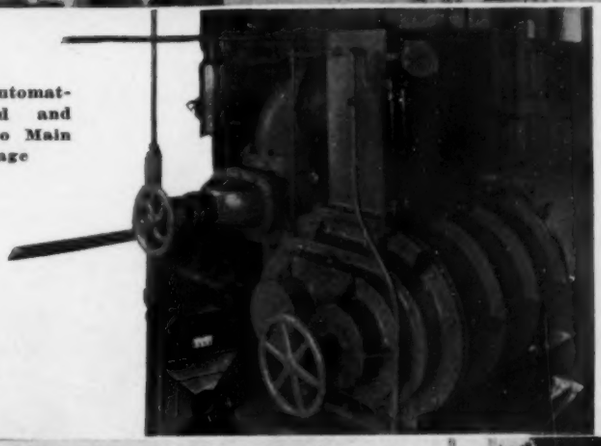
Rectifying Columns for Manufacture of Butane and Propane From Natural Gas

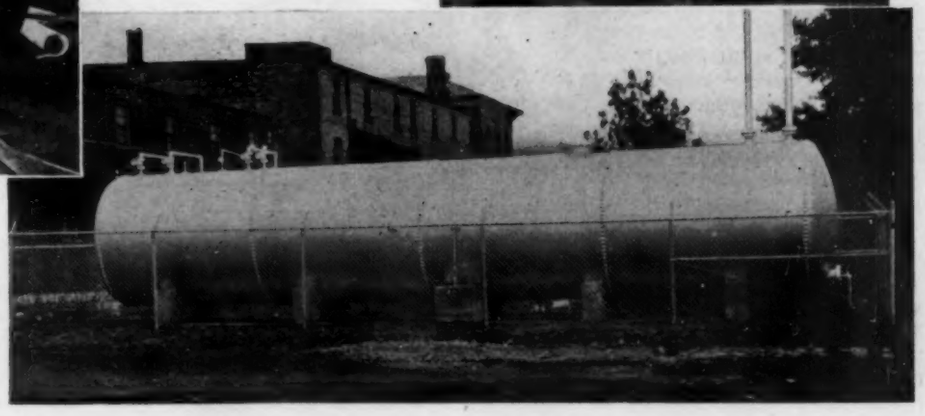
Unloading Fuel Gas From High-Pressure Tank Car to Storage



Rotary Gas Carburizing Furnaces Using Fuel Gas From Natural Gas

Fuel Gas Automatically Metered and Introduced Into Main from Storage



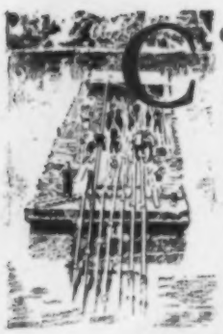


Typical Tank for Storage of Butane

Simplified Plant Design

WITH Welded Pressure

TIGHTNESS, according to the author, simplicity of design, and ease of erection and changes in the field, are inherent in welded equipment

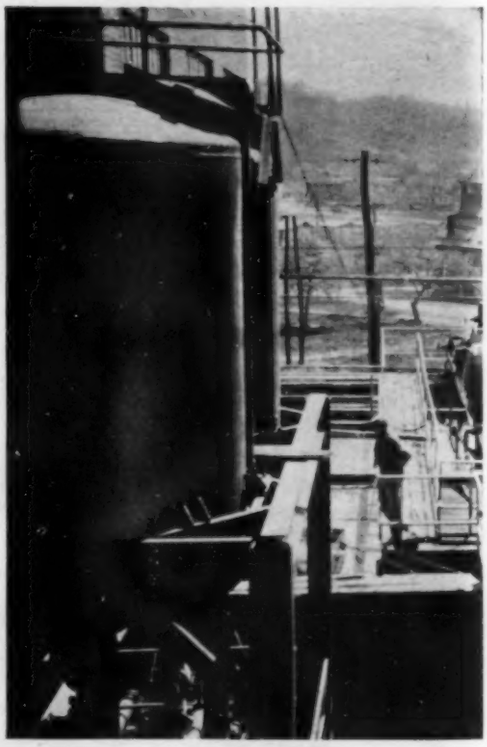


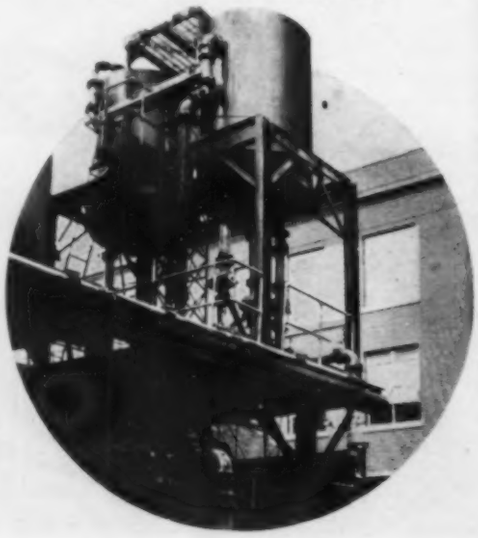
CONVERTING a laboratory process to an industrial basis may be comparatively simple if the unit operations involved can all be carried out in conventional forms of standard equipment. However, such a convenient condition is rarely found when dealing with chemical plants, especially those involving many operations at high pressures or the handling and processing of gases. Still more complicated development is confronted when the building of the plant demands that one arrange for the maximum of flexibility and change.

It is well to recognize at the start of any plant that with the development of further knowledge one may desire to modify many of the processes, perhaps fundamentally. Even in those cases where it is believed that a process is more or less definitely fixed as to flow sheet and conditions of operation, there is often the necessity for intermittent operation and the substitution from time to time of other processes requiring like equipment but intended to produce modified or perhaps altogether different products.

Under these circumstances one can well understand why any engineering staff charged with plant design is so keenly envious of the laboratory worker, who with blast lamp and glass is able to put together, take apart, remodel, or enlarge almost at will. In fact the problem of doing a like job on a large industrial scale would be almost impossible if the oxyacetylene welding and cutting equipment were not available, serving virtually as an industrial blast lamp. In fact, the planning and construction of any plant can often be done to best advantage if one views it as essentially the industrialization of such laboratory schemes of equipment building.

After determining upon the general flow sheet for any process or group of processes the design of plant equipment for each operation follows logically. The objective at each stage is, of course, correct form; durability and resistance not only to chemical attack but also to temperature, pressure, and even weather; controllable functioning; adaptability to new work; and low cost. Safety as well as considerations of preventing loss of product demand tightness, both of the unit equipment and of all connections, piping, storage tanks, etc. In the case of pressure operations or pressure storage of gases and highly volatile liquids this consideration of tightness becomes almost a dominating one. That there should be initial tightness or tightness merely under test conditions does not suffice. Assembly and jointing must be such as to give to all joints and connections a tightness and a durability substantially equivalent to that of the main structure or pipe. Furthermore, as wide a margin of safety against excessive pressures and temperatures is desired as can be obtained without excessive cost.



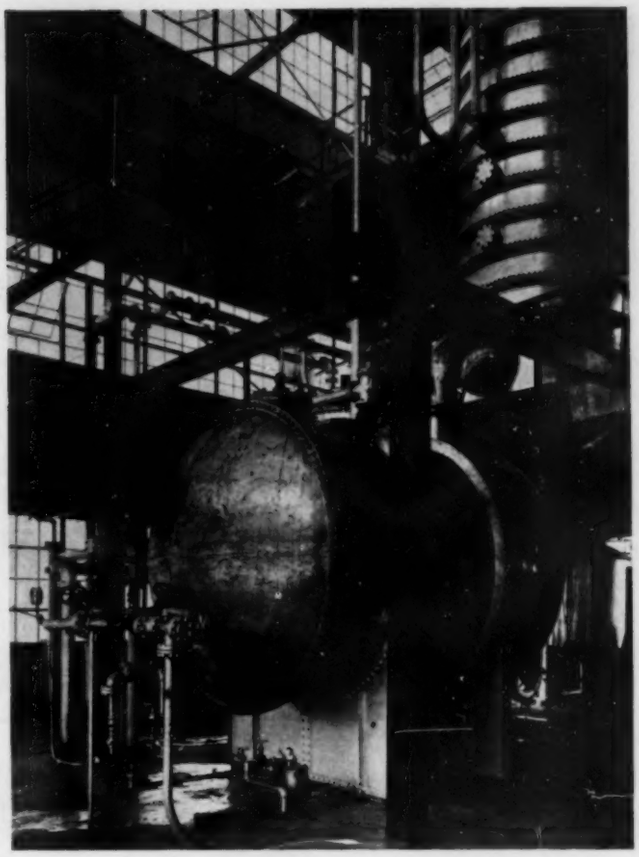


Welded Steel Equipment Is Often Lined With Glass as Are These Tanks, or With Rubber, Lead or Other Metal

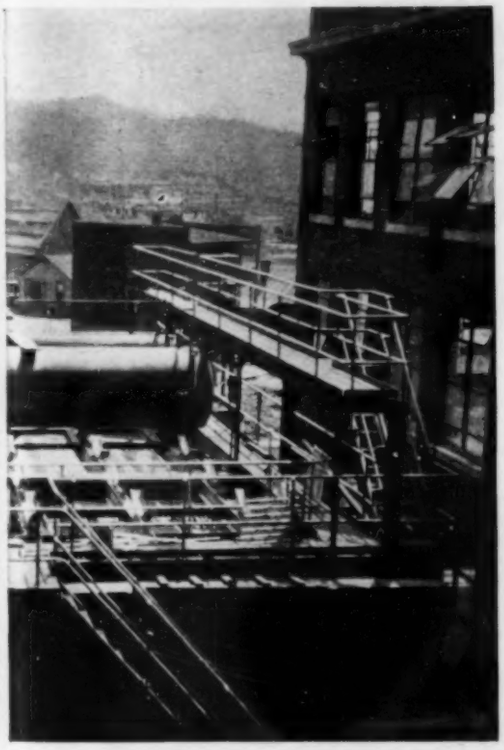
Welded joints, properly made and tested, have been found to answer almost perfectly these fundamental requirements. Experience clearly proves that such joints can be made with certainty of satisfactory result in a wide variety of materials. The opportunity to test welded equipment at pressures several

By J. N. COMPTON
Chemical Engineer
Carbide & Carbon Chemicals Corporation
South Charleston, W. Va.

Equipment



Welded Aluminum Is Used in the Fabrication of the Still and Column at the Right

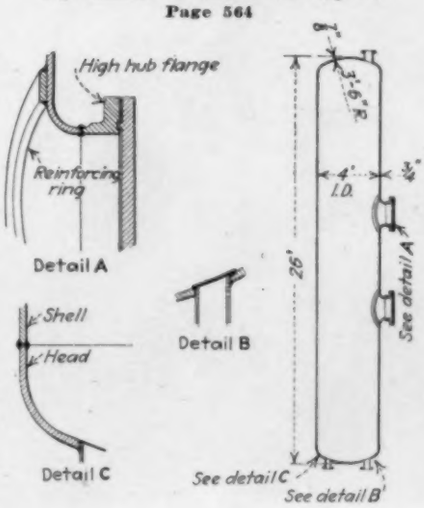


A Volatile, Flammable Liquid Is Stored Under a Pressure of 50 Lb. in the Horizontal Welded Tanks at the Left

times the maximum intended working pressures affords a measure of safety that is most satisfying to the engineer. Such tests are often not possible with riveted apparatus, because of the development of leaks under hydraulic test at temperatures and pressures only slightly above those to be experienced in use. Hence, often the engineer must content himself when testing riveted assemblies with trials that give him only a comparatively few pounds or a comparatively narrow temperature range above that at which he knows the equipment must function. Fortunately, failures of riveted equipment in service are comparatively few; but failures of welded equipment, tested at several times working pressures, are obviously likely to be still fewer.

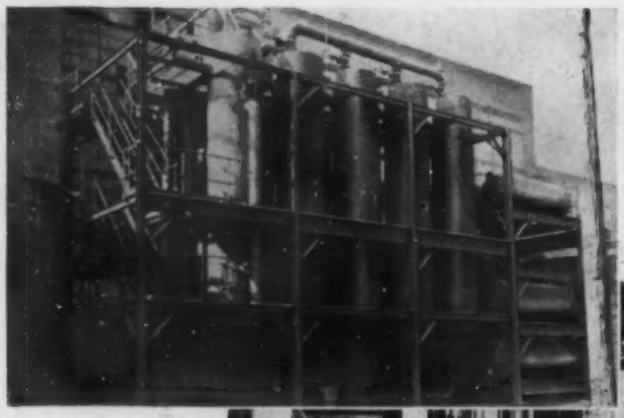
In numerous cases it is desired to carry out reactions or store materials in equipment lined with glass, rubber, lead, or other material peculiarly resistant to the chemicals involved. Where such storage or reaction must be under pressure it is, of course, necessary that the chemical-resistant lining be supported structurally by steel or other outer shell. In such cases the use of welded equipment which can be shaped with great accuracy and at moderate cost affords an important advance in equipment design. Properly trained welders can work to designs within very close tolerances, regardless of the complexity of the sections to be fabricated. This accuracy suffices to give excellent continuous support to the lining material and thus enables the building of lined devices of substantially any desired size and shape.

Construction Details of a Vessel Built for Sustaining 200 Lb. Pressure at a Temperature of 400 Deg. F.; Similar to Vessels at Top of Page 564

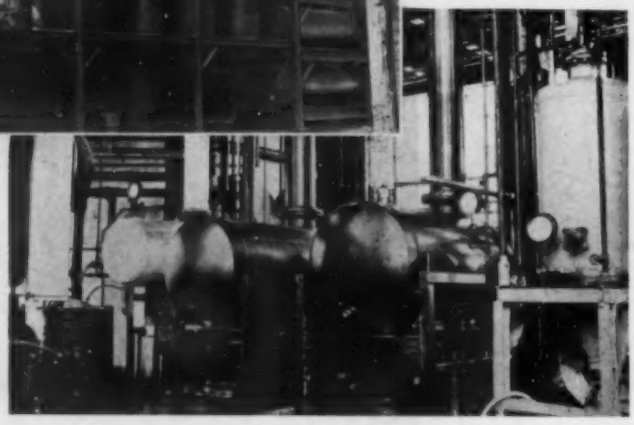


The technique of welding common metals and alloy steels is well established. The metallurgist has conclusively demonstrated that he can enhance the properties of carbon steels by the addition of chromium, nickel, and other alloying elements to give greatly increased resistance to corrosion, resistance to oxidation at elevated temperature, and high mechanical strength, both at ordinary temperature and at high temperature. By the use of the proper welding rod and proper welding technique substantially all of these alloys can be fabricated without any difficulty.

For those alloys very high in chromium any brittleness which develops during welding is rapidly removed when the equipment operates, because such alloy resumes its ductility at comparatively low temperature. Other alloys, containing both chromium and nickel, when used with a small percentage of silicon and carbon are austenitic and can be welded without necessity for subsequent heat-treatment. Even aluminum, which is often believed impracticable to use in welded equipment, can readily be applied. It often has large advantages in chemical-plant equipment because of its resistance to corrosion by nitric and acetic acids. Also it may be needed even where its inertness is not vital to avoid those con-



Left: Insulated Welded Steel Vessels for Effecting Reaction Between Liquids Under 200 Lb. Pressure at 400 Deg. F.



Right: Small Experimental Still Fabricated by Gas Welding and Lined With Lead

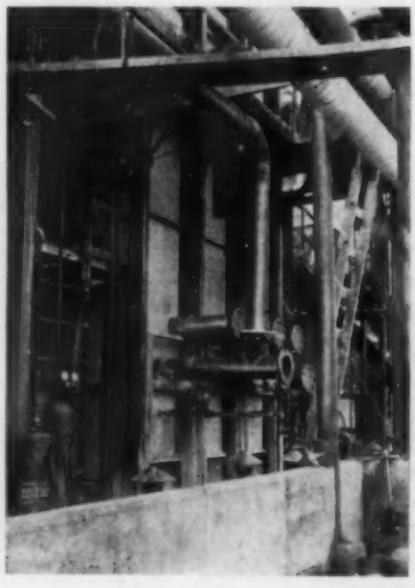
taminations which color the product when operating in other metal containers. The technique of assembly of aluminum is distinctly different, but it is entirely practicable in the hands of the skilled technician.

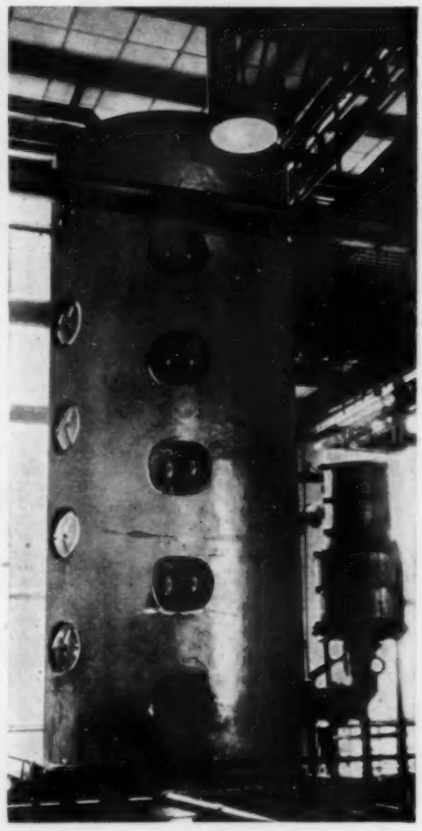
Possibly the greatest advantage from the extensive use of welding is the permissible modification of equipment during construction. Often changes in a single-unit device necessitate modification of connections or of adjoining equipment. Designs made in the field can readily be followed by the welders, and in these cases needed changes are readily made at little or no extra cost which would be utterly impracticable without returning the apparatus to the original shops if any other system of assembly were practiced. Furthermore, numerous specials, the exact form of which cannot be anticipated, may be designed on the job, and the building of non-standard equipment where necessary does not involve the unusual extra costs that are so often a burden in plant erection.

Welding has been applied in many plants to a wide variety of chemical equipment. Reaction vessels, even those intended to operate at elevated temperatures and under pressures of several hundred pounds per square inch, are so assembled. Receivers, scrubbers, separators, and storage tanks to be used in connection with the reaction vessels may be similarly made up. The interconnecting piping and the accessory equipment attached is also readily added by this method of joining. It should be the practice, however, to install at all convenient points appropriate flanged joints. These are included to permit the maximum ease of dismantling or the removal and replacement of unit equipment, when desired, without cutting of the metal. Obviously, one who neglects to include an appropriate number of flanged joints in his desire to use welding to the maximum is simply overdoing a good thing.

Use of this method of joining may also be extended to much of the accessory equipment outside of the strictly chemical plant. Natural-gas and petroleum lines, the petroleum refinery, the power plant, and a very large percentage of the plant service lines, storage tanks, and intra-plant piping can be so assembled. Typical examples of such uses are shown in the various illustrations. In any work of this sort a chemical company has available for the asking the skilled co-operation of such welding specialists as those of the Linde Air Products Company, whose experience will often increase the certainty of success in such development. That company has conclusively shown the practiability of using substantially any metal under substantially any plant conditions with successful welding of joints, provided due care is given in selection, training, and supervision of the welders. The results obtained have been economical and highly satisfactory. A bottle-tight system of either standard or special equipment is entirely feasible, and maintenance, repair, remodeling, and operation all seem to be facilitated when the initial design contemplates generous use of the welding torch as a tool of fabrication and assembly.

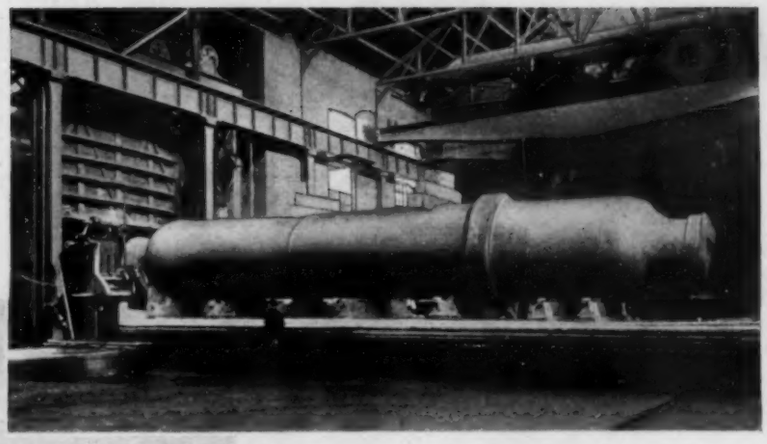
Chrome-Nickel-Iron Tubes Are Used in This All-Welded Tube Still



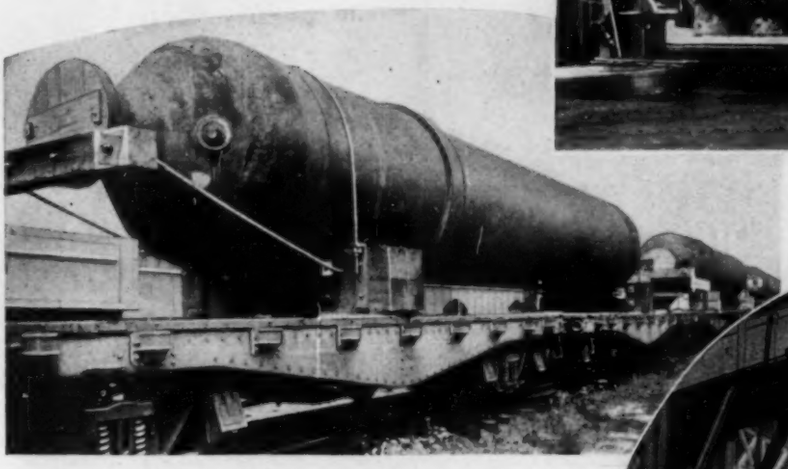


Welded, Insulated Steel Scrubber Connected to Reinforced Lead Entrainment Separator

Right: Steel Forging Necked Down at Both Ends; Over-all Length, 48 Ft. 6 In.; Inside Diameter, 58 In.; Weight, 230,000 Lb.

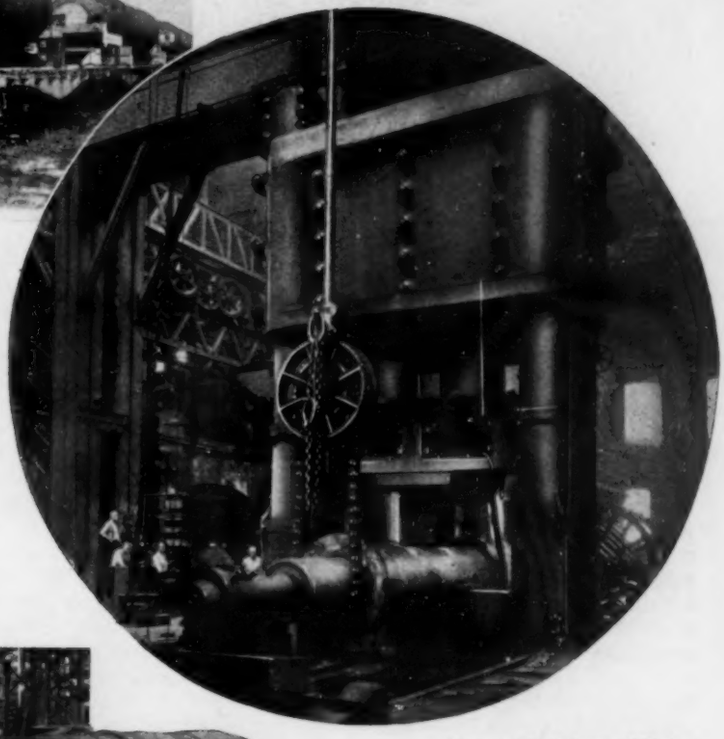


Below: Shipment of High Pressure Oil Cracking Units for Export. Length, 48 Ft. 6 In.; Inside Diameter, 72 In.; Weight, 240,000 Lb.

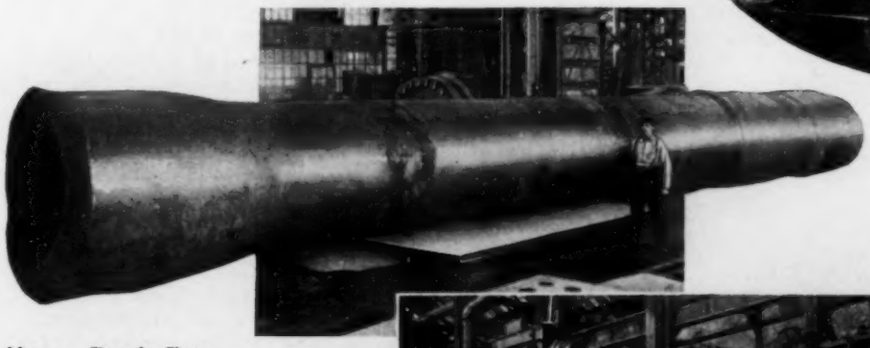


Steps in Fabricating Pressure Vessels

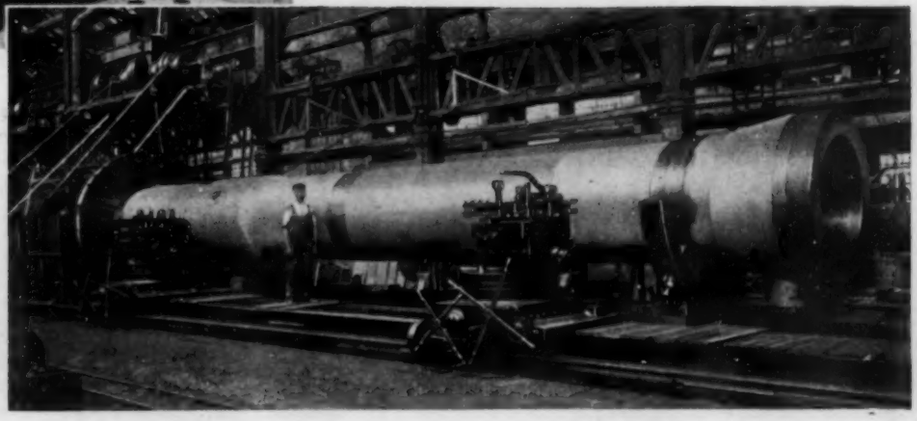
At Bethlehem Steel Company



Above: Working a Billet on the Mandrel in an Hydraulic Press. Forging Reduces Wall Thickness and Increases Length



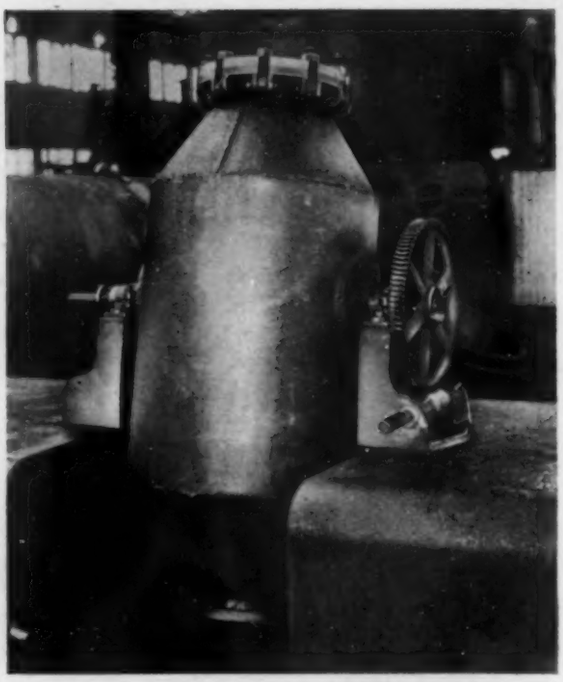
Above: Rough Forging for Vessel Shown at Right. Length, 48 Ft. 2 In.; Inside Diameter, 58 In.; Wall, 5¼ In.; Weight, 220,000 Lb.



Right: Machining Forging Shown Above. Length, 46 Ft. 7 In.; Inside Diameter, 60 In.; Wall, 3¼ In.; Weight, 119,000 Lb.

Building Reliability *Into the Pressure Vessel*

By F. O. LEITZELL
Blaw-Knox Company
Pittsburgh, Pa.



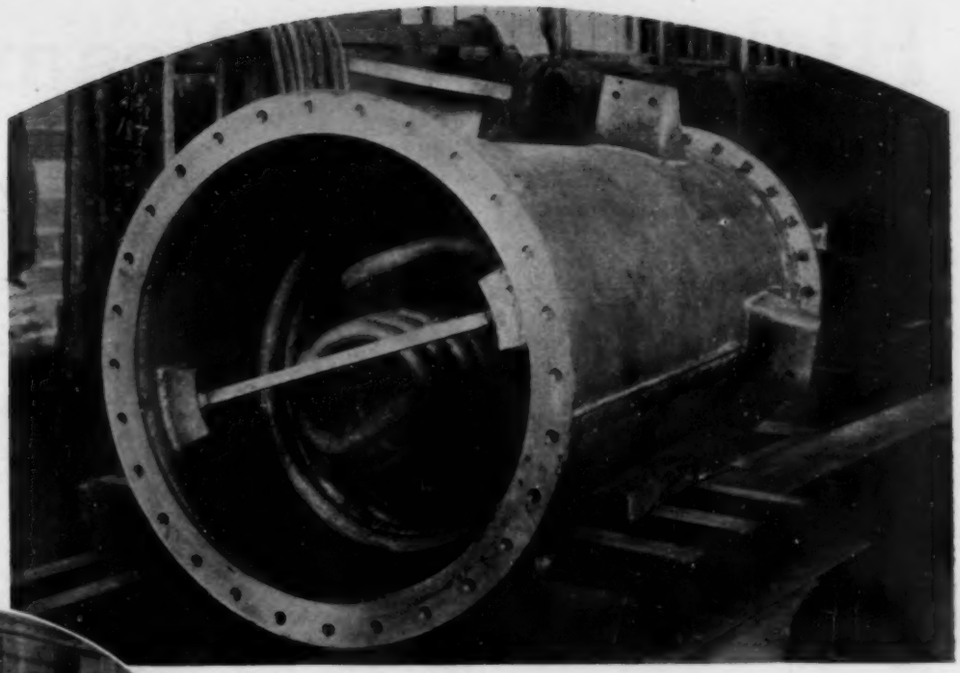
Experimental Chrome Alloy Steel Pulp Digester of ¾-In. Plate

IN DESIGNING pressure equipment, the first requirement is a complete knowledge of the conditions under which the vessel is to operate. This cannot be too strongly emphasized for when the user withholds seemingly unimportant details of the proposed operation, it may possibly result in his buying an unsatisfactory piece of equipment. The designer must know the materials to be processed, the maximum pressure, the temperature and perhaps the time cycles, the atmospheres within and outside the vessel. Having these facts, he settles on the metal to be used, and is able to choose the design and type of fabrication best suited to the requirements.

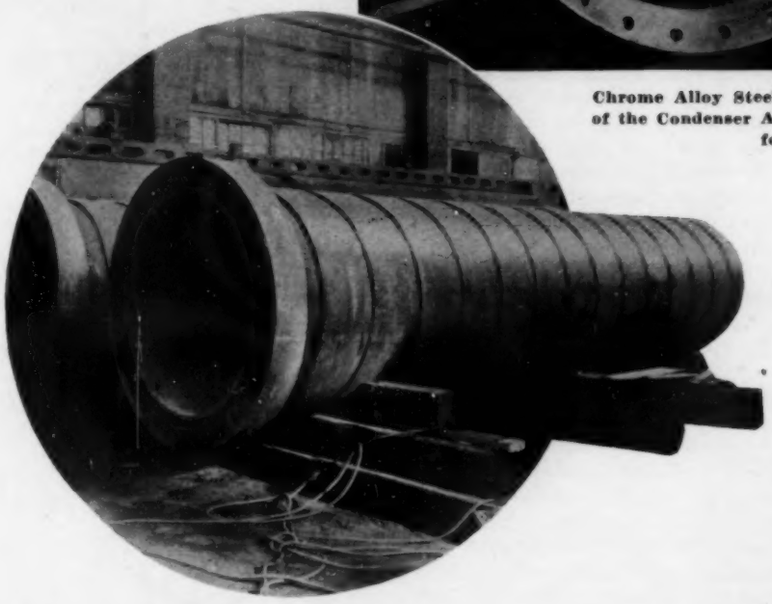
In this, consideration must be taken of safety, simplicity, expansion and contraction, metal composition and ease of fabrication. But safety in operation must be the prime requisite. If the designer knows his business, he will be able satisfactorily to provide for these factors. He will design, then, for fabrication by one or several methods: riveting, acetylene or electric welding, forge and hammer welding, or special welding processes. In the fabrication, the manufacturer will make sure that only experienced and reliable operators are used, and that they are under constant supervision. There must be continual inspection during construction and proper annealing, in one piece, to relieve all strains in welded work. Annealing temperature must be sufficient for its purpose, but not enough to deform the vessel, nor in chrome-iron and chrome-nickel-iron equipment, to form chromium carbides. After annealing the vessels should not again be heated before going in service.

Finally, adequate testing is imperative. The vessel should be stressed at least 50 per cent above the working pressure, and this pressure must be maintained a sufficient length of time to insure absolute tightness. Hammering of seams under pressure is an additional proof of proper fabrication. When the vessel has successfully undergone these tests, they give assurance to the manufacturer of the quality of his workmanship; and to the user they give confidence in the reliability of the vessel.

Forge and Hammer Welded Vessels, 10 Ft. in Diameter and 15 Ft. Long, Made of 1⅝-In. Plate. These Vessels Are Just Emerging From an Annealing Furnace Where Heat Strains Are Relieved

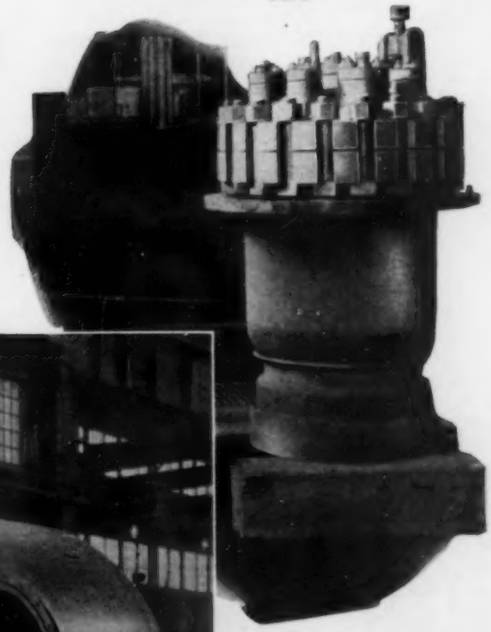


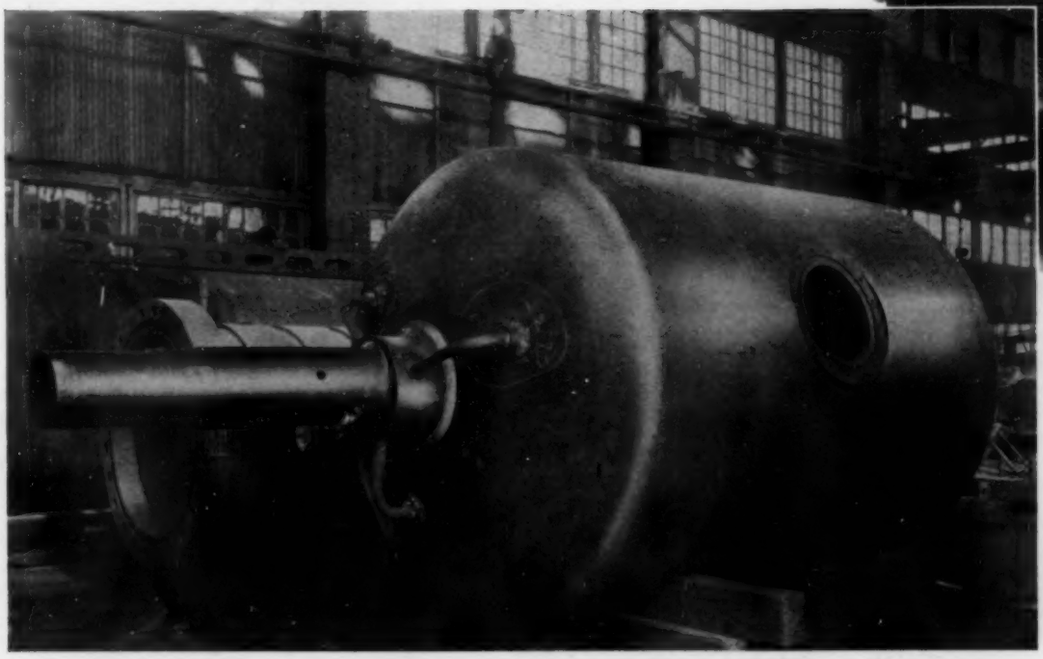
Forge and Hammer Welded Steel Bands Shrunk on the Shell of the Forge and Hammer Welded Autoclave Below Give it Additional Strength. The Shell Is 4 Ft. in Diameter and 20 Ft. Long, of 1¼-in. Plate.



Chrome Alloy Steel Plate Is Used for the Shell of the Condenser Above, and Chrome Alloy Pipe for the Coils

Below, This Oil-Fired Steel Autoclave, 30 In. in Diameter, Made of 1¾-In. Plate, Is Designed for 1,000 Lb. Working Pressure





Double-Walled Vessels Present a Construction Problem. This Steel-Plate Carbonator, 6 Ft. in Diameter and 10 Ft. Long, Has a Forge and Hammer Welded Inner Vessel of 1¼-In. Plate and a ¾-In. Jacket, Fabricated by Electric Welding. The Vessel Is Designed for a Constant Steam Supply as it Rotates

High-Pressure Steam—

A Money Saver in Process Plants

By PHILIP W. SWAIN
Associate Editor, Power

IN FIVE YEARS high-pressure steam — that is, steam at pressures of 1,000 lb. and up—has evolved from a laboratory curiosity into a full-fledged commercial reality. In this development the electric utility industry, aided by research organizations and equipment manufacturers, has played a leading part. Yet, strange to say, industrial process plants generating part or all of their own power requirements will reap much of the profit by intelligent use of the high-pressure equipment thus made commercially available and by application of the experience gained in high-pressure operation.

In the central-station field in America alone there are now six plants operating in the 1,200-1,400 lb. range. Five or six other plants for similar pressures are in various stages of design and construction.

One industrial power plant with reciprocating engines exhausting to process will soon be in operation at 1,800 lb. Another (the Masonite Corporation) has employed 1,200 lb. steam pressure directly in process work for several years. Approximately 100 industrial plants employ pressures between 400 and 800 lb., the majority of these in the 400-500 lb. range. Although these latter pressures are not "high" as the term is defined in the first paragraph or as it is understood in central-station work, they do represent a distinct advance in industrial practice.

IN EUROPE steam is generated commercially at the critical point (about 3,200 lb.) in one plant and at pressures approaching 2,000 lb. per square inch in several others. There, boilers of special design are commonly employed for high-pressure work.

In America on the contrary, all of the 1,200-1,400 lb. boilers so far constructed have followed the general designs of moderate pressure boilers but with parts suitably strengthened. The chief change is in the drum, which is almost invariably forged as a single seamless piece of steel, with walls about 4 in. thick.

New opportunities opened to the process engineer by commercial development of high-pressure steam equipment of proved reliability fall in two divisions: process and power.

First, and most obvious, is the direct application of high-pressure steam to process uses. A study of the skeleton steam tables on page 569 (based on the Keenan Tables issued this year by the American Society of Mechanical Engineers) indicates that the chief field for direct application of high-pressure steam will be in processes requiring temperatures of 600 deg. F. or less.

TRUE, saturated steam may have a temperature as high as 706 deg. F. (critical point), but the latent heat available at this pressure (3,226 lb.) is zero. Even 600-deg. steam requires a pressure of 1,545 lb. and can furnish less than half of its available heat above 32 deg. F. by condensation. The remaining heat of the liquid cannot be transferred at the saturation temperature but may be returned to the boiler as high-temperature feed water or released in preliminary process heating at a low temperature.

It seems to me, subject to correction by chemical engineers who are more familiar with process requirements, that process applications of high-pressure steam will be confined in the main to temperatures where a substantial portion of the heat is available in the latent form and where the pressures for which equipment must be built are not extreme. There may, for example, be many process uses for steam in the vicinity of 1,000 lb. absolute (545 deg. F.) and below.

For higher temperatures other substances, such as diphenyl, may supply the necessary temperature and latent heat at much lower pressures and hence at lower equipment cost. Mercury vapor is another possibility for the upper temperature ranges. Chemical plants interested in this can learn much by studying the extensive experience of the Hartford (Conn.) Electric Light Company with the mercury-vapor boiler developed by the General Electric Company.

At pressures under 1,000 lb., saturated steam is an ideal heat-transfer medium, capable of delivering huge quantities of heat through surfaces of moderate area, and inherently adapted to close temperature control. Since saturated vapor at constant pressure maintains a constant temperature regardless of variations in the rate of heat transfer, saturated steam has a distinct temperature-control advantage over electrical heating. The latter is fundamentally a constant-energy-supply method, with temperatures that must fluctuate with the rate of heat absorption unless the energy flow is thermostatically controlled. Moreover, steam heat, controlled by pressure alone, automatically maintains a uniform temperature over the entire heated surface.

Assuming that the great majority of process operations will continue to require steam pressures of 125 lb. gage and less, the greatest value of high pressure in the process plant will be as a means of increasing enormously the power obtainable as a byproduct of the process steam load, rather than in direct process applications.

This is where the process plant can show a far larger gain from high pressures than can the central station where all steam is exhausted to the condenser at pressures approximating ½ lb. absolute.

As the back pressure is increased, the power obtainable by a given rise in initial steam pressure at the turbine throttle becomes a greater and greater percentage of the total.

WHERE process steam is used at, say, 125 lb. pressure, little by-product power can be produced with boiler steam at 200 lb. supplied to turbines, which in turn exhaust to process. Forcing this pressure up to 500 lb. increases the power obtainable from the same flow of process steam more than 200 per cent. The additional fuel required to accomplish this should be less than 5 per cent.

A good idea of the effect of pressure on power capacity may be obtained from the accompanying diagram. This is a somewhat idealized "indicator card" for a turbine or steam engine.

Readers who have forgotten most of their steam engineering may be reminded that the indicator card is merely a pressure-volume graph for the expansion of steam in a turbine or engine. In such a graph areas represent work obtainable.

If the curve in this diagram is

assumed to represent the expansion of 100 lb. of steam per hour through a turbine, each black or white area represents the development of 1 kilowatt. The usual losses have already been allowed for on the basis of a 70 per cent stage efficiency with all heat losses returning to the steam as reheat. This is close enough to average conditions to give the diagram some value for preliminary estimates. Final estimates should, of course, be based on actual turbine guarantees obtained from the manufacturers.

Steam conditions have been so assumed in this diagram as to give dry saturated steam at atmospheric pressure on the expansion line. The diagram is therefore particularly adapted to the study of cases where the process pressure is close to this point. If, however, the process pressure falls at some higher point such as 35 lb., 70 lb., or 124 lb., the diagram will still give a fair indication of the amount of power obtainable.

The chief difference then will be in the superheat and moisture conditions at the throttle and at various points along the expansion curve. In order, for example, to obtain saturated process steam at 70 lb. gage, rather that at 0 lb., it would be necessary to lower the superheat at the turbine throttle approximately 80 deg. below that indicated on the diagram. This is, of course, an advantage because superheat temperatures above 750 deg. may cause operating troubles. Incidentally, if the indicated superheat is too high, it may be lowered if some moisture in the exhaust is not objectionable.

With these preliminary remarks we may study the diagram to see how initial and final pressure affects the power obtainable from a given flow of steam. Assume first that the back pressure (process pressure) is 0 lb. gage and the initial pressure 200 lb. The power obtainable from 100 lb. of process steam per hour will then be 5 kw. (5 areas on diagram). By running the initial pressure up to 480 lb., this can be increased to 7 kw., a gain of 40 per cent. If the initial pressure is increased to 705 lb., the power will be increased by 3 kw., or 60 per cent.

If one makes the same jumps in initial pressure starting with a higher back pressure the *percentage* gain in power will be greater, although the actual increase will be the same.

A POWER ENGINEER'S approach to the process problem might be as follows. He would first ask the chemical engineer to set the process pressure as low as possible without injuring the product or retarding production. Then he would ask for a daily load curve for process steam and a similar curve for electrical energy demand.

Next, assuming an initial pressure, he would plot from the process demand curve a curve of byproduct power available. This would be compared with the curve of actual power demand. If the initial pressure were too low to deliver the required power as a byproduct at all hours of the day, the operation would be repeated assuming a higher pressure.

In practice it may not pay in all cases to carry the pressure to a point where all power requirements can be generated as a byproduct of process steam. Certain short and high peaks of power demand require such substantial expenditures for higher pressures that it may be cheaper to generate this small quantity of power by condensing units or to obtain it by purchase.

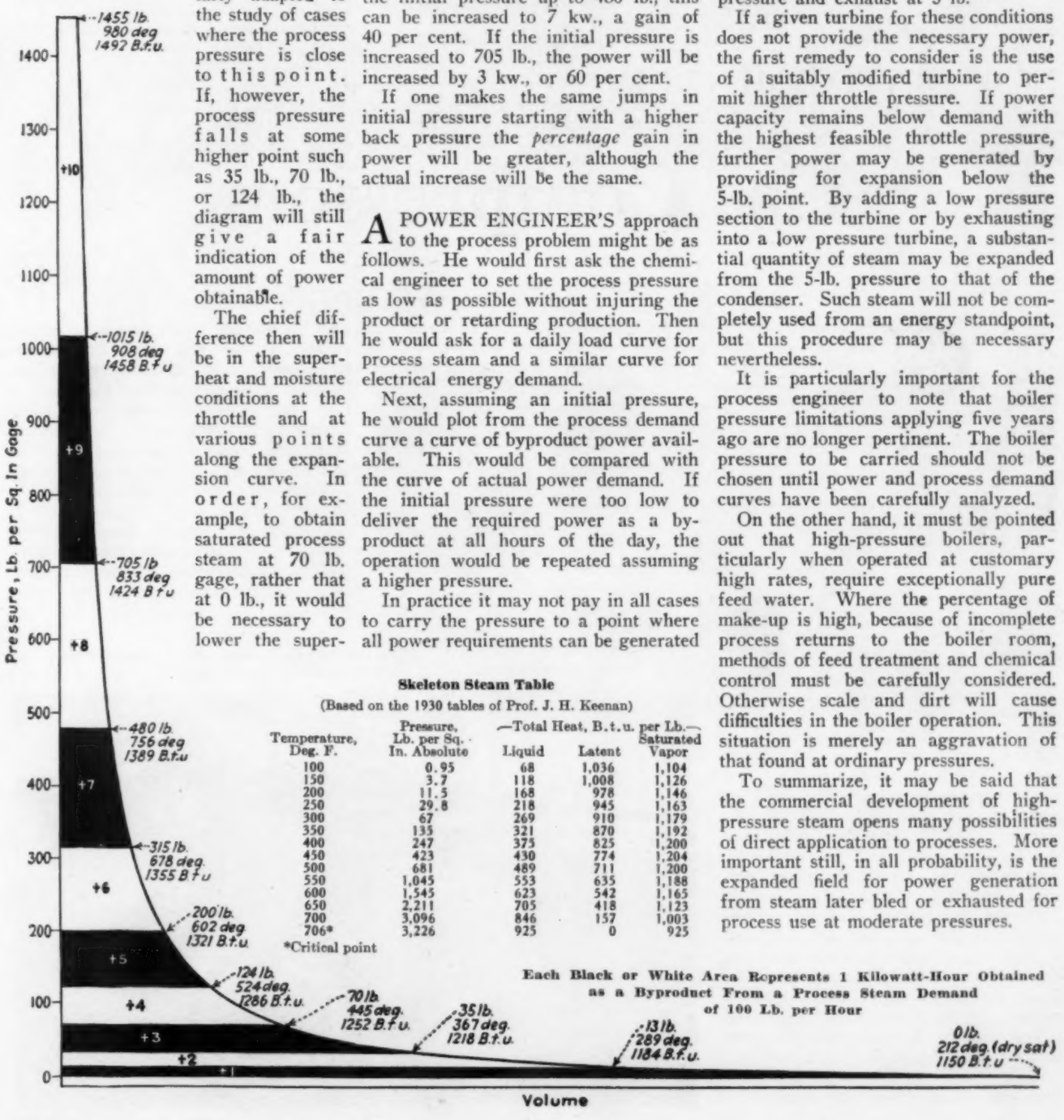
The possibilities of "bled" or extracted steam are perhaps not fully realized by all process engineers. Steam for process may be bled from a turbine at practically any pressure required and at several different pressures simultaneously. For example, a certain plant requires process steam at 125 lb., 50 lb., and 5 lb. gage pressure (the latter including steam requirements for building heating). It is perfectly feasible to buy a turbine to bleed at 125 and 50 lb. pressure and exhaust at 5 lb.

If a given turbine for these conditions does not provide the necessary power, the first remedy to consider is the use of a suitably modified turbine to permit higher throttle pressure. If power capacity remains below demand with the highest feasible throttle pressure, further power may be generated by providing for expansion below the 5-lb. point. By adding a low pressure section to the turbine or by exhausting into a low pressure turbine, a substantial quantity of steam may be expanded from the 5-lb. pressure to that of the condenser. Such steam will not be completely used from an energy standpoint, but this procedure may be necessary nevertheless.

It is particularly important for the process engineer to note that boiler pressure limitations applying five years ago are no longer pertinent. The boiler pressure to be carried should not be chosen until power and process demand curves have been carefully analyzed.

On the other hand, it must be pointed out that high-pressure boilers, particularly when operated at customary high rates, require exceptionally pure feed water. Where the percentage of make-up is high, because of incomplete process returns to the boiler room, methods of feed treatment and chemical control must be carefully considered. Otherwise scale and dirt will cause difficulties in the boiler operation. This situation is merely an aggravation of that found at ordinary pressures.

To summarize, it may be said that the commercial development of high-pressure steam opens many possibilities of direct application to processes. More important still, in all probability, is the expanded field for power generation from steam later bled or exhausted for process use at moderate pressures.

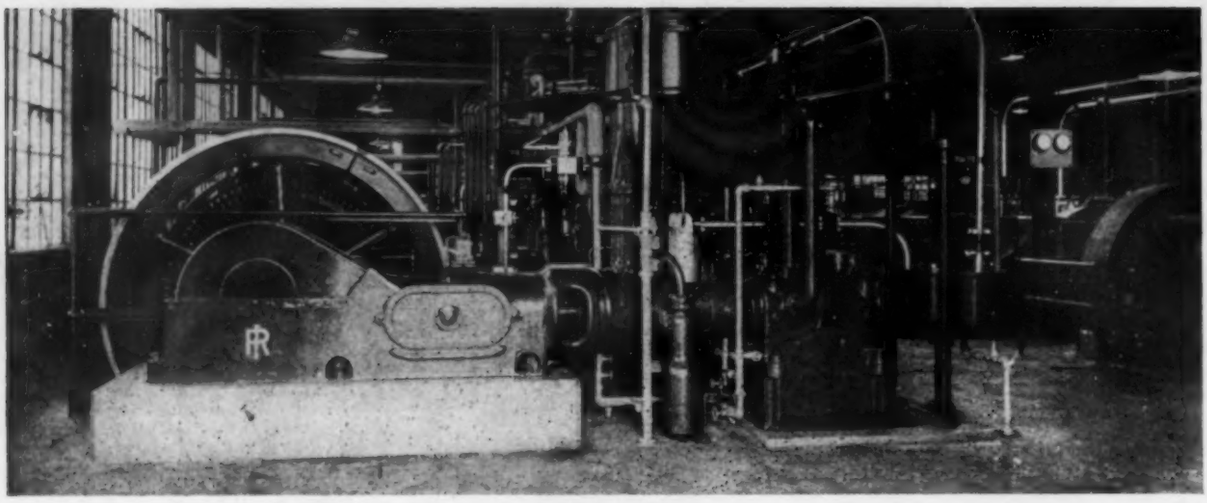


Skeleton Steam Table

(Based on the 1930 tables of Prof. J. H. Keenan)

Temperature, Deg. F.	Pressure, Lb. per Sq. In. Absolute	Total Heat, B.t.u. per Lb. — Liquid	Latent	Saturated Vapor
100	0.95	68	1,036	1,104
150	3.7	118	1,008	1,126
200	11.5	168	978	1,146
250	29.8	218	945	1,163
300	67	269	910	1,179
350	135	321	870	1,192
400	247	375	825	1,200
450	423	430	774	1,204
500	681	489	711	1,200
550	1,045	553	635	1,188
600	1,545	623	542	1,165
650	2,211	705	418	1,123
700	3,096	846	157	1,003
706*	3,226	925	0	925

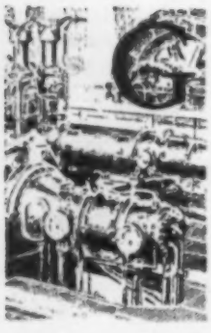
*Critical point



Battery of 6-Stage Compressors in Mathieson Alkali's Ammonia Plant

NEW DEVELOPMENTS IN

Gas Compressors



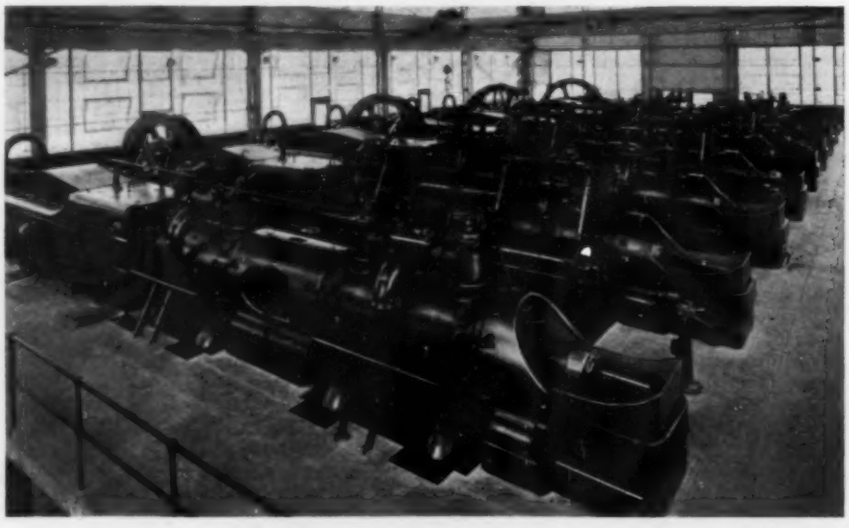
GAS compressors are among the more important pieces of equipment necessary in the large-scale operation of modern high-pressure developments. For this kind of service only multi-stage machines are suitable, and the following is a brief review of recent developments and a discussion of problems arising in the construction of high pressure, multi-stage gas compressors.

Two-stage machines are suitable for discharge pressures between 80 and 500 lb. per square inch, three-stage up to 1,200-lb., and four to five stage up to about 5,000-lb. pressure. Seven- and nine-stage machines have been built for discharge pressures up to 15,000 lb. per square inch. The question of how many stages to use usually is answered by considering the cost of inter-stage cooling. As the number of stages is increased, the cost of power for compression is lowered, but the additional cooling units required rapidly cut down the saving. German practice seems to favor the use of more stages than is common in this country, but this usually is at a sacrifice of compression efficiency, and the gain, therefore, is not obvious.

Compressors suitable for use in recent chemical developments are required to handle corrosive gases. To meet the difficulties of corrosion and wear, good practice provides for lining the cylinder with corrosion-resistant materials and also for constructing parts such as valves of stainless steel. Since continuity of operation is an essential requirement, simplicity and accessibility have been emphasized in recent design. In particular, the valves and packing, which are parts most liable to cause shut-down, must be arranged so as to be easily adjusted or replaced. A corollary development has been so to design the stuffing boxes that a minimum number is required. For example, a three-stage single-acting compressor can be built with one stuffing box, and a four-stage machine is on the market having two stuffing boxes. Even more surprising developments in this matter of stuffing-box elimination are under way.

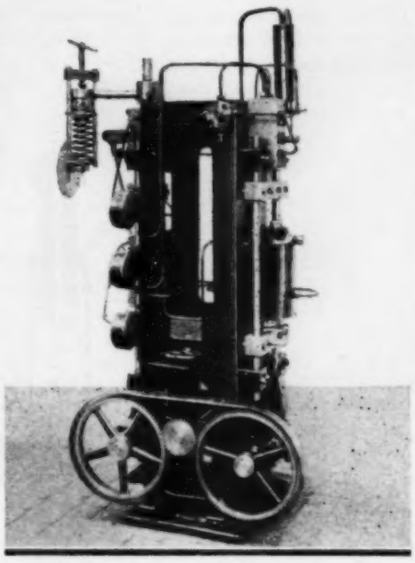
Volume control can also be obtained without varying the compressor speed. A satisfactory way of accomplishing this is to have adjustable clearance control, particularly on the early stages, in a multi-stage unit. For example, in

Twin Tandem 4-Cycle Double-Acting Gas Engine Compressors at Baton Rouge (La.) Station of Southern Gas & Fuel Company



a four-stage machine, operating with a 5,000-lb. discharge pressure, a 25 per cent reduction in volume can be obtained by clearance control on the first and second stages. While compressor installations in chemical plants usually are designed for a given capacity, experience has shown that a duplication of units is desirable in order to obtain flexibility. The selection of the number of units as well as the number of stages is an economic one. The size of units seems to be limited pretty largely by the manufacturer's shop facilities and by the number of units to be built. In other words, mass production is a large factor in determining the economical size of compressors. There is no engineering reason why much larger units than are at present in service should not be built, but limited production puts such machines in a class with special equipment and means corresponding high unit cost.

Recent developments have practically eliminated mechanically operated valves and confined the design to automatic plate or poppet valves. Another tendency has been to lengthen the stroke of the machine and to increase the piston and rotating speeds. Machines having a piston speed of 600 ft. per minute and 100 r.p.m. are finding favor. Design engineers emphasize the fact that gas speeds should not be too high in these compressors. Many of the difficulties centering around the valves can be reduced by reducing the gas speed through the valves.



Recent foreign developments are very interesting. In this section a Sulzer hyper compressor is described which involves a new principle in the operation of the higher stages. This machine is mechanically operated in the first five stages and the sixth and seventh are operated by means of hydraulic oil pistons. This development has as yet not taken hold in this country and it will be interesting to follow the result in Europe. Another foreign manufacturer of compressors is the Amsler Company, which markets an extremely high pressure gas compressor suitable for use up to 4,000 atmospheres. While this machine must be regarded as experimental, nevertheless the engineering difficulties successfully solved in its construction are tremendous and should shed light on similar difficulties in standard machines. The Fixed Nitrogen Research Laboratory is experimenting with a 1,000-atmosphere gas compressor, and results from that laboratory will be awaited with interest.

THE HYPER COMPRESSOR

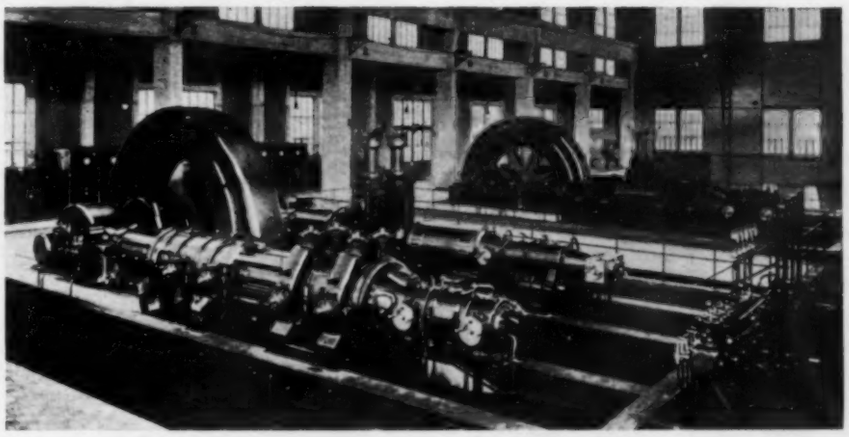
By R. W. MILLER

Arolsen, Waldeck, Germany

THE tremendous development which the nitrogen industry has undergone during the last few years and the great national importance which has been attached to it by various countries has aroused much interest in the machines employed in this industry. Among the large machines the gas compressors are predominant, and among these the hyper compressors, working at a final pressure of about 1,000 atmospheres.

The development of these machines dates back to the pioneer work of Georges Claude, who was the first to recommend the use of very high pressures for ammonia synthesis. Sulzer Brothers took up a leading position in the technical development of machines of this description some three years ago, and introduced a type which differs radically from these hitherto known.

The starting point of the development was the well-known large Sulzer gas compressor for pressures up to 300 atmospheres. These machines were constructed with as many as six compression stages, and from a theoretical point of view it would be sufficient to add a further stage to the 300-atmosphere machines so as to obtain a pressure of 1,000 atmospheres.



Sulzer 1,000-Atm. Hyper Compressors; Suction Volume, 4,500 cu.m. per Hour; Power Required, 2,000 B.H.P.

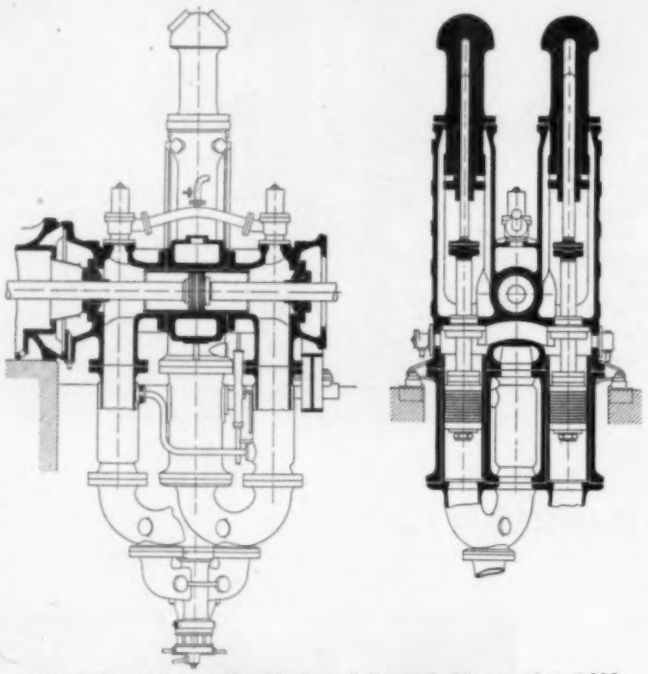
The fundamental characteristics of the Sulzer hyper compressor is the vertical arrangement of the cylinders for the sixth and seventh stages; these cylinders are operated hydraulically by means of columns of oil and are referred to in the following description as hyper stages for brevity. Embodied in this arrangement is the idea of regarding the hyper stages as more or less separate machines.

The design of the Sulzer hyper compressor may be seen by referring to the illustrations, which show the machine which was recently supplied to the Compagnie de Bethune S. A., Bully-les-Mines. The compressor is designed to deal with an effective suction intake of 4,000 to 4,500 cu.m. per hour at a final pressure of 1,000 to 1,100 atmospheres. It is driven by a three-phase motor of the flywheel type mounted on the shaft, the motor delivering a constant output of approximately 2,000 hp. at the normal speed of 122 r.p.m. Two such units have been laid down for the time being, but a number of similar compressors are planned. The machine has a two-throw crankshaft, the first, second, and third stages being operated by one crank and the fourth and fifth together with the primary oil cylinder by the other. All the horizontal cylinders are fitted with detachable and interchangeable

cast-iron liners, having the well-known Sulzer type of fixing flange in the middle, so that expansion may take place freely toward both ends of the cylinders.

The cooling water jackets are made in two parts, thus making the water-cooling chambers accessible at all times for cleaning and also obviating as far as possible any indeterminate stresses in the cylinder walls as would otherwise be the case with integral cooling jackets. The first and second stages have disk pistons which float on the piston rod and, therefore, cannot cause uneven wear on the cylinder walls. The piston rod is made in two parts for each side of the machine, with a knuckle joint connection in the slipper between. This facilitates erection and also brings the main bearing surfaces outside the cylinder, assuring their being amply lubricated and easily accessible. Metallic packing of the Kraus type is used for all horizontal glands and the glands themselves are arranged so as to be adjustable from the outside. The cylinders are mounted flexibly on the bed plates so that alterations of length, consequent upon warming up, can take effect freely. For this purpose sliding surfaces which may be lubricated are provided under the cylinder feet. Spring loaded ring valves are employed up to and including the fifth stage, their construction being of the ordinary and well-known type. Their chief characteristic is small weight, which enables them to operate silently and dependably even at a comparatively high rate of speed. The valve seatings may, if necessary, be divided up into a number of interconnected rings, which provide an opening of large cross-section with a very small lift, thereby providing an approximately perfect indicator diagram.

Mention should also be made of the four bearings provided for the crankshaft in two forked frames. Both the double crank and the entire gearing are inclosed in an oil- and dust-proof casing, lubrication being effected automatically from a large oil container located in the basement and provided with an interchangeable filter arrangement. Oil circulation is maintained by means of a gear-wheel oil pump, driven direct from the shaft. A separate forced lubricating, reciprocating pump supplies oil to the cylinders and glands.



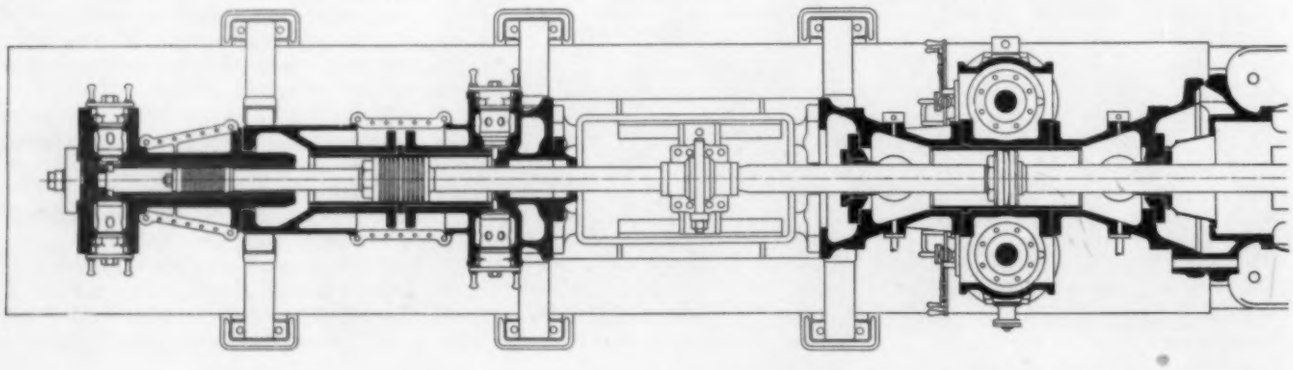
Hydraulic Drive of the Sixth and Seventh Stages of a 1,000 Atm. Sulzer Hyper Compressor

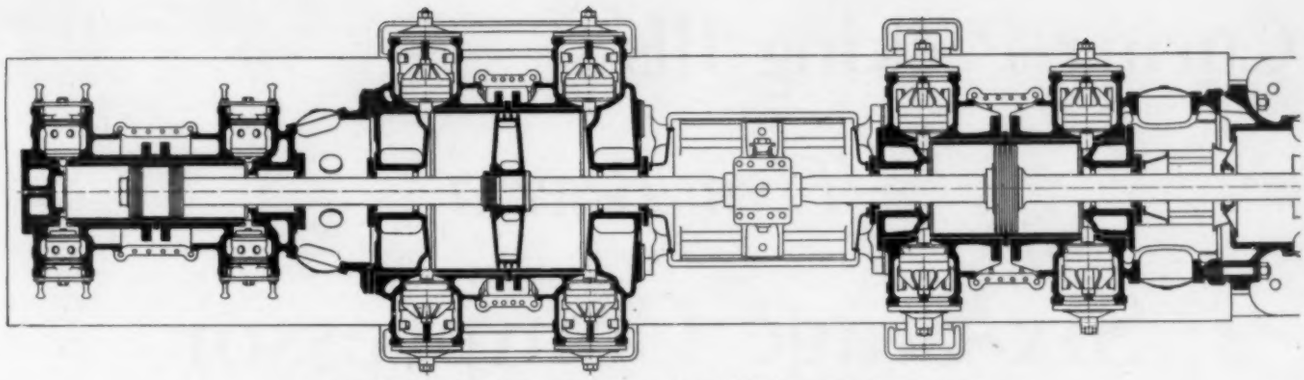
The chief item of interest in this machine, however, is the two hyper stages. As already mentioned, they are shown in detail in the sections and elevations. The primary oil cylinder is fitted between the frame and the cylinder for the fourth stage on the high-pressure side of the machine, while the secondary oil cylinders stand at both sides of the primary oil cylinder, with the gas cylinder on the sixth and seventh stages arranged vertically on top. The arrangement is as compact as possible, so as to obtain a short column of oil. An oil pipe of ample size runs from both sides of the primary oil system to below each of the secondary pistons in such a way that the motion of the primary system is transmitted direct to the secondary pistons by means of hydraulic columns. Unavoidable loss of oil through leakage, blowing off of valves, or the limitation of the stroke, as mentioned below, would shorten the column and thereby tend to make transmission of movement inexact. Such loss is compensated automatically by the supplementary feeder pump after each stroke, thus making transmission of movement exact.

Each side of the transmission column is rendered safe from excessive stress by the provision of safety valves. Should a plunger stick for some reason or other, no damage would be caused to the machine, as would otherwise inevitably be the case with a purely mechanical means of operation, as the appropriate safety valve would open and the oil pressure column would collapse. In other words, after the plunger concerned has stopped working, the machine can run on safely for some time; that is, until the attendant has been able to stop it. The plungers are connected by means of flange couplings to the piston rod of the secondary oil piston, while the gas cylinders themselves are placed into the frames from above. Dismounting the cylinders is, therefore, very easy, as the cylinders with the plungers and glands may be lifted out from the top by a crane after undoing the coupling bolts and fixing both in the cylinder frame. In the same way, a replacement cylinder made ready previously can be fitted in, so that the duration of any interruption of operation as a result of changing plungers can be reduced to less than an hour.

Objection has already been raised to the method of operation with hydraulic

Longitudinal Section of the 1,000 Atm., First to Fifth Hyper Compressor



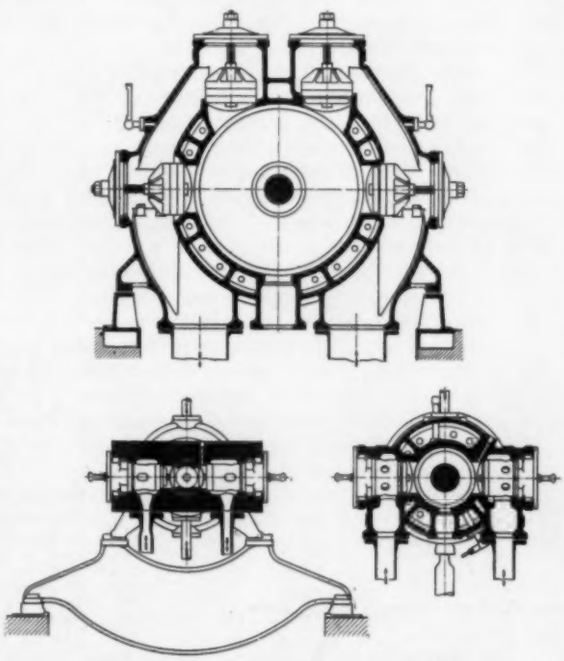


Second, Third, and Fourth Stage Sulzer 1,000-Atm. Gas Compressor

columns by saying that it renders operation more difficult. Exactly the opposite is actually the case, since the hydraulic column needs no lubrication and no attention and is in itself rendered safe, as already mentioned. Experience in actual working has shown that it fully satisfies the highest demands which may be made on the machine in regard to reliability in operation. It should be mentioned, incidentally, that it is quite easy to arrange matters in such a way that the hydraulically operated cylinders can be disconnected from the rest of the machine while at work and brought to a standstill, and that without any interruptions in working, a spare machine having only hyper stages can be brought into operation. A combination of this description has already been tried out in practice and has given very good results. Nevertheless, it constitutes a certain amount of complication in operation that is sometimes undesirable.

The hyper cylinders are made of a specially tough Siemens Martin steel and are of the typical mushroom form, as will be recognized from the sectional drawing; this form corresponds approximately to a body of uniform strength. The mushroom heads contain the valves and the great thickness of the walls provided there is necessary because of the weakening of the material by the radial arrangement of the valve borings. A cooling jacket is not considered necessary, but it can easily be fitted if required by special circumstances. On the other hand, the plungers are internally cooled by water which is conducted through a central boring and run in and out by means of pipes in the usual way. Cooling is augmented by an ample circulation of oil in the front gland, which is constructed in such a way that the plunger moves in a continuous bath of cold oil.

The stuffing box is fitted with flexible throat elements, four for the sixth stage and five for the seventh stage. The elements are located singly in steel chambers, and their angles, which vary from element to element, are arranged so that the drop in pressure inside the packing itself gives as far as possible an even tightening up of all the elements. There is a bronze guide above the throat element which guides the plunger, keeps all large impurities out, and also serves to take up a portion of the reduction of pressure. The front gland is situated lowest of all. It likewise contains flexible packing elements and serves mainly as an oil scraper as well as for cooling the plunger by means of a circulation of cool oil. Lubrication of the actual packing is effected in several places which are connected to corresponding delivery systems of the high-pressure oil pump and the arrangement is such that the oil supply to each individual lubrication point can be accurately controlled at all times. It will be readily understood that lubrication of the glands is extremely important.



Vertical Section of the 1,000 Atm. First to Fifth Stage Hyper Compressor

The main characteristic of the valves for the highest pressure is the valve head without a guide. The valve head hangs on the spring, and as long as the spring is free to move, even an encrusted valve will act properly. The place of contact on the valve seating alters with each stroke, as the valve head operates with a dancing movement. As a result, mechanical impurities are automatically removed from the seating surfaces and the valve seating does not wear the valve heads. The stroke of the valve can be adjusted as required by suitable formation of the valve stop which at the same time serves the machine as a spring guide.

A further exclusive characteristic of the Sulzer hyper compressor is the limitation of stroke of the plunger for the sixth and seventh stages. This permits the stroke of the plunger to be adjusted, which is technically equivalent to altering the clearance. If the limitation of stroke is shifted downward the plunger at the top of the stroke is lower and the cylinder affected thereby operates with an increased clearance. The reverse holds good in the case where adjustment is set for a greater stroke. By this means the utmost consideration can be extended to new conditions by altering the capacity.

The two hyper compressors of Bethune have been in service since the beginning of this year. A pressure of 1,000 atmospheres was obtained without trouble by both machines, so that they could at once be put into continuous service at full load. Measurements taken at the official trials showed that each compressor handled 4,534 cu.m. of mixed gas per hour, reduced to 15 deg. C., and 760 mm. of mercury, the net power required as measured at the shaft being 1,056 boiler horsepower. The suction volume, therefore, is, about 12 per cent more and the power required about 2½ per cent less than guaranteed. The compressors have not been stopped more than 5 per cent of the extraordinarily large 3,000 normal working hours.

Curing Packing Ills

That Beset a

Six-Stage Compressor

By H. A. SOMMERS

Assistant Superintendent, Ammonia Plant
Mathieson Alkali Works
Niagara Falls, N. Y.

PACKINGS in high-pressure compressors are a fertile source of difficulty. During four years of operation of three six-stage compressors in the Mathieson Alkali Works' ammonia plant, much trouble was experienced with the fifth stage packing of these machines.

Suction pressures in this stage vary between 450 and 800 lb. per sq.in. and the discharge pressure between 1,450 and 2,000 lb., depending upon the capacity at which the compressors are operated. Average suction and discharge pressures in this plant are 650 and 1,800 lb. respectively.

For packing, a conventional type has been used, consisting of nine steel cups or cases, each containing two metal packing rings. Fig. 1 shows a packing assembly, while in Fig. 2 the rings are illustrated in detail. In our compressors, which have 3-in. diameter piston rods, the rings were 4¼ in. O.D. x 3 in. ± 0.0005 in. I.D. x ⅛ in. wide. The radial cut ring was placed on the pressure side of the "tangential" cut ring in each packing case. Each type consists of three equal segments which are aligned in the packing cases, so that the joint in the "tangential" ring is sealed horizontally by the radial ring. Both types of ring are held in position by garter springs having comparatively slight tension. Side clearance in the cases is maintained at 0.0015 to 0.002 in. Bore of these cases is 3⅛ in., (to take care of rod misalignment) giving a ring overhang (difference of internal radii of ring and case) of ⅛ in.

Observations With Old Style Packing—Lubrication was by means of an oil lantern placed between the fourth and fifth cases from the pressure end. Three McCord pump units operating at full stroke supplied Texaco number 636 special compressor oil (viscosity, 1,526 Saybolt seconds at 100 deg. F.)

Despite the fact that lubrication appears always to have been sufficient, exceedingly variable results were obtained and much trouble was experienced with scored rods and packing. Leaks were numerous. An investigation was initiated to determine the principles involved in metal packing construction and operation and to design a packing which would be satisfactory. At the start of the investigation cast-iron packing rings of the type shown in Fig. 2 were used. The principal difficulty was scoring of the rod. This consisted of a deposition of cast iron on the rod which gave a very rough, hard, and spotted surface, quickly rasping out the rings and causing immediate leakage. A packing of high-lead bronze was tried and although it was much better, there was still a certain amount of scoring. In this case the rods simply grooved and leaked and if taken down soon enough could usually be polished by hand and made fairly serviceable.

Rods wore excessively, however, wearing as much as 0.0001 in. per day with bronze packing. As might be expected, wear increased as the rod became less uniform in diameter. At 0.01 in. wear, further wear progressed very rapidly. With three different rods, extent of wear was plotted against stroke. In all examples the point of greatest reduction was concentrated about 5 to 8 in. from the piston end of the stroke. Maximum pressures existed

Fig. 1—Conventional Type of Packing in High-Pressure Compressor

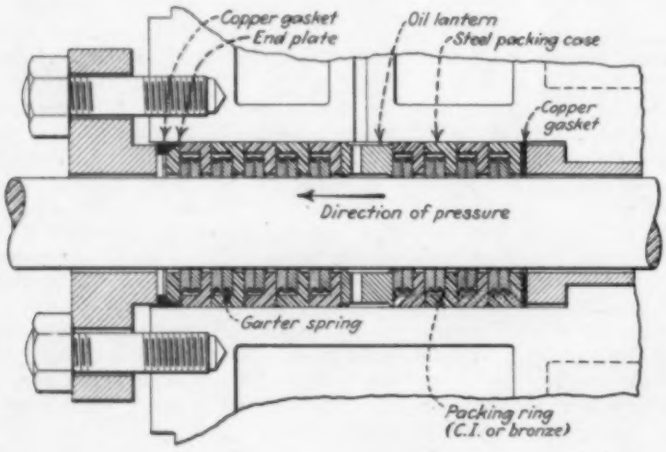
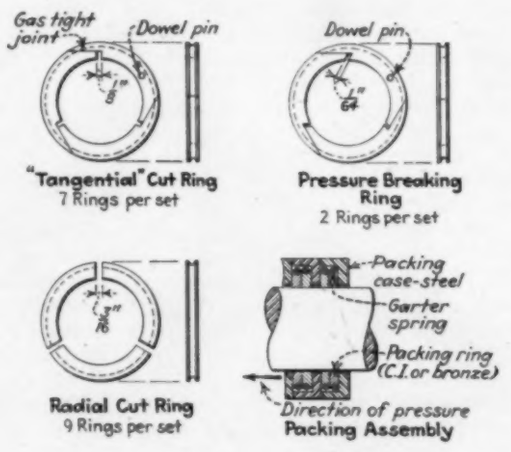


Fig. 2—Details of Conventional Type of Packing for High-Pressure Compressors

Rings at the left are "packing rings" while that at the right is a "pressure-breaking ring," used with a radial ring in each of the first two cases. The two rings at the left are used in pairs in each of the remaining cases. Lower right sketch is a detail of installation.



in the fifth stage cylinder at this point and caused excessive pressure of the rings on the rod.

The conventional type of packing shown at the upper right in Fig. 2 is designed to become non-collapsible after a certain amount of wear has taken place, by virtue of the small gap, about $\frac{1}{64}$ in. It is obvious that when this has taken place, the rings become valueless as a seal. In wearing in the rings, the rod wears at the same time and cannot give the desired fit. On this account, the chief function of the first two pairs of rings, which is to reduce the pressure to a point which will prevent undue wear on the remaining collapsible rings, is undermined by the more or less localized wear at the inner end of the stroke. The burden of sealing is then thrown upon the remaining seven cases.

When the packing is first put into operation, the full fifth stage pressure causes the ring to bear on the rod with a pressure which is extremely high as can be demonstrated by a simple calculation. Using the dimensions of the

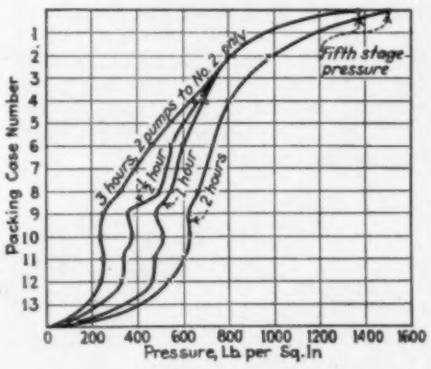


Fig. 3—Pressure Gradient in a 13-Case Packing of Special Type

Packing consists of 10 solid rings and three packing rings. Two oil pumps were used on case No. 2, two on No. 4 and one on No. 8 except in the "3-hour" test, as noted. Note effect on pressure of the wearing in of the rings and the better pressure breakdown, exhibited in the "3-hour" test, with the lesser quantity of oil. Curve labels indicate time after start of test at which measurements were made.

"tangential" ring given above, and assuming a fifth stage pressure of 2,000 lb. exerted on the outside perimeter of the ring, we find a unit bearing pressure on the rod of $\frac{2{,}000 \times 4.18}{2.95} = 2{,}840$ lb. per sq.in. where 4.18 is the calculated external and 2.95 is the calculated internal peripheral area of the ring. This assumes no outward balancing force between the ring and rod. If pressure were to balance completely on both sides of the ring, the bearing pressure would be $\frac{2.000 \times (4.18 - 2.95)}{2.95}$ = 835 lb. per sq.in. As it is not known how much of the balancing pressure exists, it may be stated that the unit bearing pressure lies somewhere between 835 and 2,840 lb. per square inch in the first packing case. This net pressure is evidently excessive and unquestionably is responsible for the spotting and scoring of piston rods.

Investigation of New Packings—It appeared that the problem of producing a trouble-free, long-wearing packing could be attacked from five angles: (1) reducing bearing pressures; (2) increasing surface hardness of the rod; (3) improving lubrication through control of quantity and point of application of oil; (4) decreasing ring overhang; and (5) using more satisfactory packing material.

Use of a packing consisting of ten solid "pressure-breaking" rings, followed by three ordinary packing rings, was suggested by the Garlock Packing Company. All rings were made of high-graphitic cast iron. They were ground and lapped to a clearance of about 0.001 in. on the rod diameter. This packing was provided with $\frac{1}{8}$ in. diameter holes (similar to those in Fig. 4) extending from connections in the outer flange through the walls of the packing cases to the various rings. It was thus possible to introduce oil to Nos. 2, 4 or 8 cases singly or together. It was also possible to measure the pressure on most of the cases by joining the flange connections to two manifolds, one connected to a 3,000-lb. gage and the other to a 1,000-lb. gage. The connections to the manifold made it possible to measure the pressure at any single case or to bypass any or all cases, causing the packing to work with any given number of units up to 13, by operating the valves connected to the two manifolds.

Pressure at the various cases, when the compressor was started, was found to vary from minute to minute. This was due to the large amount of oil pumped to the packing. Fig. 3 shows pressure tests made at four different periods after the start of the test. Lower pressures were obtained in the "3-hour" test, due evidently to reduced oil feed.

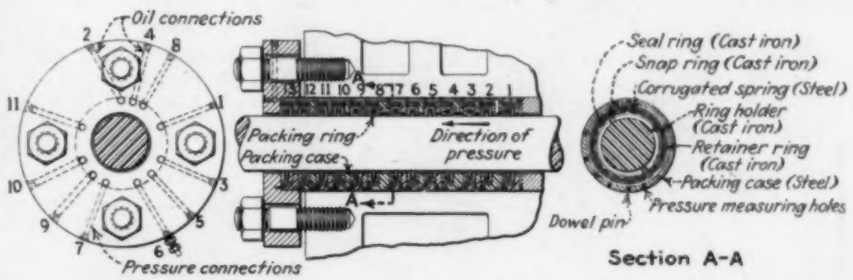


Fig. 4—Piston-Ring Type of Packing Installed in Compressor

Left view shows oil and pressure connections in the packing flange leading to the various cases. View at the right shows the various components of a single seal ring of this type.

This packing was almost completely leak proof at the start but leaked increasingly, and finally quite severely, after 18 hours. It would seem that the wear on the rings and rod, since the rings were non-collapsible, must have been due to the eroding effect of the oil and gas leakage. Increase in oil feed seemed to assist in sealing the gas leakage. With an oil flow of about

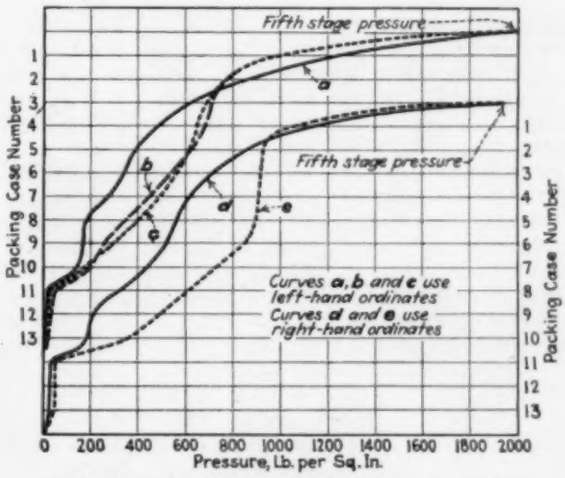

Fifth stage pressure
Fifth stage pressure
Curves a, b and c use left-hand ordinates
Curves d and e use right-hand ordinates
Packing Case Number
Packing Case Number
Pressure, Lb. per Sq. In.

Fig. 5—Pressure Gradient Through a Special Piston-Ring Type of Packing, Showing Effects of Varying Oil Quantity and Point of Application

Curves *a*, *b* and *c* vary point of oiling, using full stroke of one pump on a different case for each curve; *a*, pump connected to No. 2 case; *b*, pump connected to No. 4 case; *c*, pump connected to No. 8 case. Curves *d* and *e* vary quantity of oil, using first one-half stroke of one pump to each of Nos. 2, 4 and 8 cases in curve *d*; and then full stroke of one pump to each case in curve *e*.

$\frac{1}{2}$ pint per minute, fed to the packing at about 2,000 lb. pressure, it was possible completely to eliminate all gas leakage.

Oil then flowed out around the rod in a continuous stream. After this test, however, leakage was worse than ever, and the rod was spotted and rough as

it had been found to be with ordinary cast-iron packing.

Starting from this point the writer, in conjunction with the Garlock Packing Company, designed a packing which incorporated several important changes (Fig. 4). This packing uses the same cases as before, but substitutes a single special ring for the conventional pair in each case, a "seal ring" built like an ordinary piston ring except that it is in two halves with a step-cut joint at either side. The ring is $\frac{1}{4}$ in. wide, $\frac{1}{16}$ in. thick and has a $\frac{1}{16}$ in. allowance for wear at the step-cut ends. A snap ring $\frac{1}{4}$ in. wide and $\frac{1}{8}$ in. thick encircles the seal ring to prevent gas leakage. A ground joint seals the juncture between the seal ring and the snap ring. The latter has a gap about $\frac{3}{8}$ in. wide which is located by a pin with respect to the seal ring so that the various joints cannot line up. The ring assembly fits into a ring-holder which in turn accurately fits the packing case. Between the snap ring and the holder is a light corrugated spring which serves to give a slight contracting effect to the seal ring. The ring holder consists of two halves and a $\frac{1}{4}$-in.-thick retainer ring, which holds together the entire assembly.

The seal ring is $3\frac{1}{8}$ in. O.D. x 3 in. I.D. x $\frac{1}{4}$ in. wide. Its external area is $3.375\ \pi \times 0.25 = 2.65$ sq.in.; its internal area $3.0\ \pi \times 0.25 = 2.36$ sq.in.; and the unit bearing pressure on the rod, calculated as before, is 2,250 lb. per sq.in. If the balancing effect previously evaluated is considered, the net pressure is 246 lb. per sq.in. Therefore, where with the conventional type of ring, the bearing pressure was somewhere between 835 and 2,840 lb. per sq.in., with the new ring it is between 246 and 2,250 lb. per sq.in.

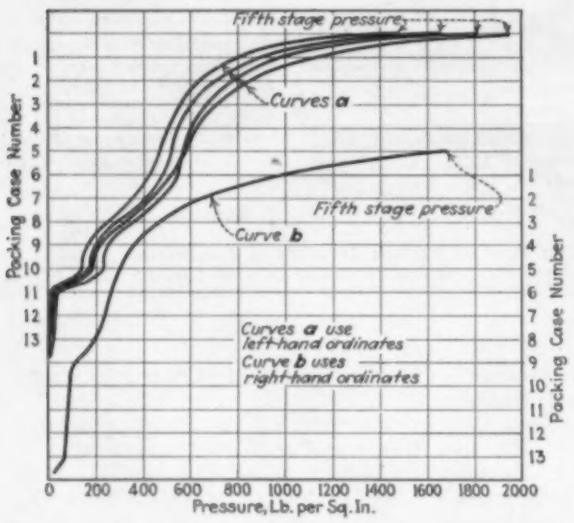

Fifth stage pressure
Curves a
Fifth stage pressure
Curve b
Curves a use left-hand ordinates
Curve b uses right-hand ordinates
Packing Case Number
Packing Case Number
Pressure, Lb. per Sq. In.
0 200 400 600 800 1000 1200 1400 1600 1800 2000

Fig. 6—Comparison of Pressure Gradient of Piston-Ring and Tongue-and-Groove Packings

Curves *a* vary fifth stage pressure from 1,950 to 1,480 lb. In each, one-half stroke of one pump is supplied to Nos. 2, 4 and 8 cases. Curve *b* shows pressure gradient exhibited by special tongue-and-groove type of packing

With the conventional packing, the ring overhang was noted to be $\frac{1}{16}$ in. for a new rod. Unequal rod wear unbalances the overhang and tends to tilt the rings in the cases. This causes the ring to stick and bind. With the new rings, however, the ring holder fits the rod to 0.001 in. There is, it is seen, practically no overhang and no tendency for the seal ring to tilt.

Packing of this type was installed on one compressor and was provided, as in Fig. 4, with connections for changing the point of oil application and for taking the pressures at the various cases. The curves in Fig. 5 show the building up of pressures at or near the point of oil introduction, first when this point is varied, and then when the quantity of oil feed is changed. Curves *a* in Fig. 6 show pressure variation in the different cases as the fifth stage pressure is varied. As a result of these tests it was decided that a small quantity of oil, $\frac{1}{2}$ stroke of one pump, should best be introduced to each of Nos. 2, 4 and 8 cases. It is obvious that too much oil does harm rather than good, in that it builds up higher pressures than need be, and erodes both rings and rods.

With the piston ring type of packing, either the high-lead bronze mentioned above or cast iron should be about equally as good. Bronze rings, however, are not nearly as likely to score when used on a rod having a Brinell hardness of about 200. The Brinell of the bronze in question is 45, and of the cast iron, 100 to 135.

At present writing, the piston-ring packing has been in operation 90 days and the rod wear is 0.0015 in. on the diameter. Most of this wear took place during the first week, while the packing was wearing in. There has been no gas leakage whatsoever at any time during the run. The rod has not acquired an extremely high polish, being somewhat dull in appearance. This is due to the cast iron of the packing. Bronze would give a considerably higher polish. Believing that harder rods would probably result in less wear and give better anti-friction properties, we made up several rods of "Nitralloy G." These were very smooth and uniform and had a hardness of about 900 Brinell. Because of the complexity and expense of the piston-ring type of packing, a new type, shown in Fig. 7, was used. This is, in effect, the combination of two conventional type rings in a single ring. Its three-piece tongue-and-groove construction is designed to seal both horizontal and radial leakage. It was developed by the Garlock Packing Company.

Rings of this type were installed on a second compressor together with an accurately fitted "Nitralloy" rod. This leaked about $\frac{1}{2}$ cu.ft. per minute throughout the 60-day test. At the end of the test, however, the 13 rings were practically unworn, the rod had acquired a high polish, and was in excellent shape except that it was worn about 0.002 in. on the diameter. A pressure gradient curve for this packing is shown in Fig. 6*b* in comparison with similar curves for piston-ring packing. It is interesting to note that the tongue-and-groove ring appears to break the pressure more rapidly than the piston ring in spite of its permitting some leakage.

It is the writer's belief, based on experience gained in the various tests, that piston-ring type of packing, using a Nitralloy or other hard rod, will give the best results for high-pressure work. No exact data are available to determine the proper number of cases for any given pressure. As much as 2,000 lb. pressure has been packed successfully with as few as six cases of the piston-ring type. It is felt, however, that a larger number, up to 13, should be used for continuous service. The number is variable, depending upon such factors as lubrication, condition of the rod, packing and pressure.

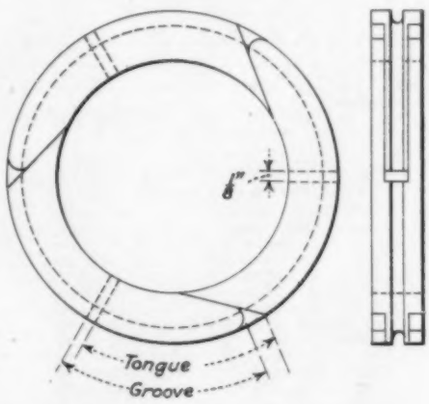
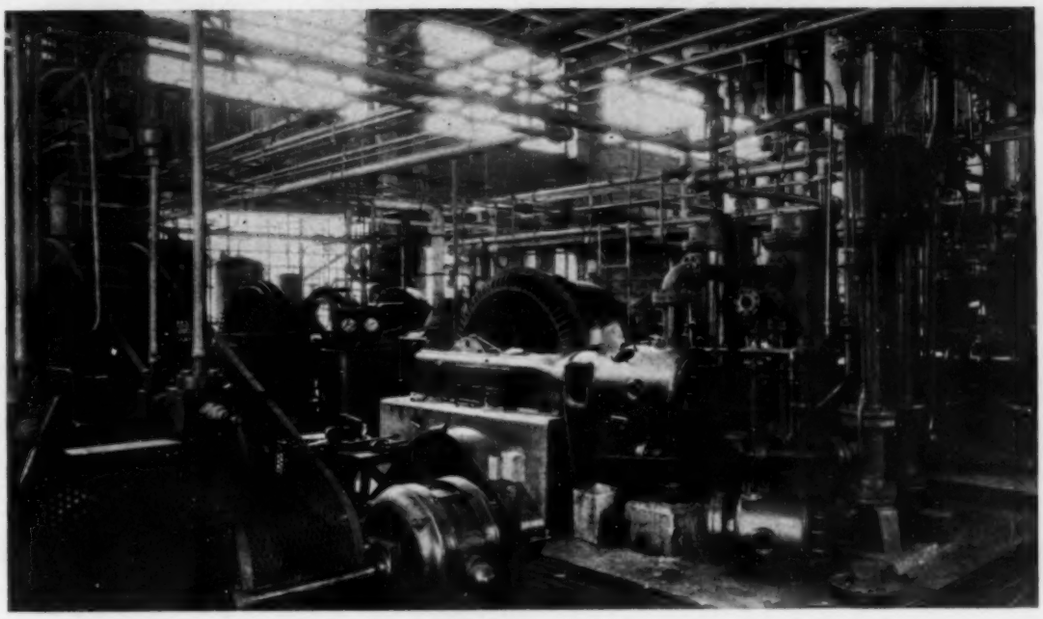


Fig. 7 — Details of Tongue-and-Groove Type of Packing Made of Cast Iron or High-Lead Bronze

Compressor design permitting, the rings may be installed in grooves in the rod, as are piston rings in a piston. In such an installation, a long cast iron sleeve of sufficient length is used instead of a recess as for the conventional type of packing. It is understood that this design is now being used quite successfully.

Piston-ring packing is being applied to a pressure of over 4,500 lb. in this plant, but data are not yet available. A 15,000-lb. installation is soon to be equipped with similar packing. These higher pressures should yield some very interesting information.



Experimental Plant of the Du Pont Ammonia Corporation is a Proving Ground for New Equipment Designs

Technique and Equipment

For High Pressures

WITH the increasing use of high pressures and temperatures in industries has come the development of an entirely new technique. Transporting gases and liquids in piping and tubing, regulating the flow by means of automatic and hand-operated valves, and particularly connecting up various units in a process in an easily accessible and safe manner, have made necessary radical modifications of established engineering practice. While pressure industries are comparatively new, there has already been evolved a group of engineering principles that guide the design and construction of pressure accessories. Some of these principles are discussed in the following brief survey with the aid of typical diagrams showing constructional features. Much of this material originated at the Fixed Nitrogen Research Laboratory; other material was obtained from pressure plants in operation and from manufacturers of equipment identified with these new developments.

Space limitation precludes adequate discussion of types of materials suitable for accessory construction. In another place more extended consideration is given to this matter. In general there are available the carbon steels, alloy steels, and non-ferrous alloys from which to choose. Chrome vanadium steel has found wide application in pressure equipment construction and the stainless steels are coming more and more into common use. Selection must be made on the basis of the temperature and pressure met in practice, with careful consideration of the corrosive action of the materials to be handled. This article is concerned only with constructional features which have been found satisfactory under a wide variety of operating conditions.

Tubing and Connectors—One of the most common joints in a pressure operation involves tubing either joined to another piece of tubing or connected to a valve or other device. Tubing can be obtained in almost any size desired within the limits of an inside diameter to outside diameter ratio of one to three. There are even some exceptions to this.

Fig. 1 shows six kinds of joints. *A* illustrates one method of making an end to end joint of two heavy wall tubes. The ends of these tubes are machined at right angles to the tube axis and a small gasket groove is cut in each end as shown. A thin copper gasket is placed between the ends of the tubing. Both tubes are cut with a left-hand thread and a collar is screwed on one and a nut on the other. By means of a threaded coupling the tubes are drawn tightly together. *B* is essentially the same connection except that it is more suitable when a tube must be joined to a large piece of equipment such as a converter. In that case the nut replaces one of the tubes and is provided with gaskets at each end as shown. *C* is a useful arrangement when a projection can be machined on the body to which the tube is to be joined. *D* and *E* show two slightly different modifications of a tube joint in a valve body. In this case the ends of the tubes are machined to a 59-deg. cone, threaded to receive a left-handed collar and seated by means of an externally threaded nut. This kind of a joint is not so readily disassembled as those shown in the three previous drawings, as it is necessary to bend the tube in order to remove it from the valve. This, of course, presupposes some flexibility. The advantage, of course, is that no gasket is used. The *D* arrangement permits the use of a shallower hole but wider in diameter; the *E* arrangement makes it possible to use a deeper and narrower hole. *F* is an end to end joint suitable for use with rather large diameter tubing. In this case the ends of the tubes are machined slightly spherical and threaded to receive flanges. A copper-plated "doughnut" is inserted between the ends of the tube, fitting the spherical surface. Pressure is applied by means of bolts through the flanges. The steel used in the construction of the "doughnut" should be very soft.

Piping—Fig. 2 shows four arrangements suitable for use in joining the

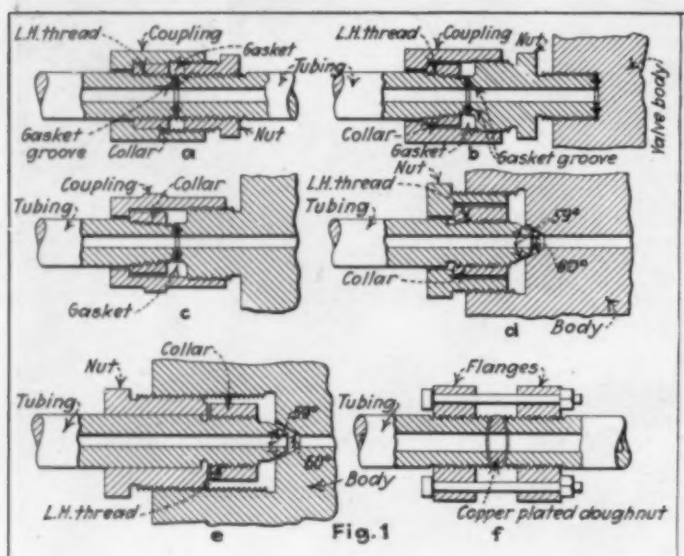


Fig. 1

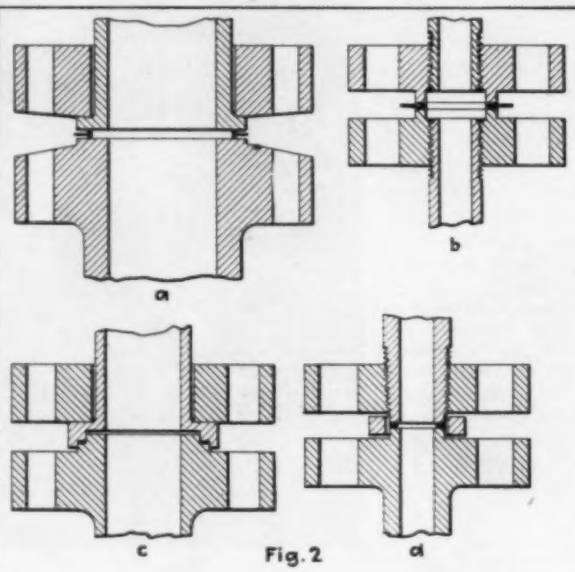


Fig. 2

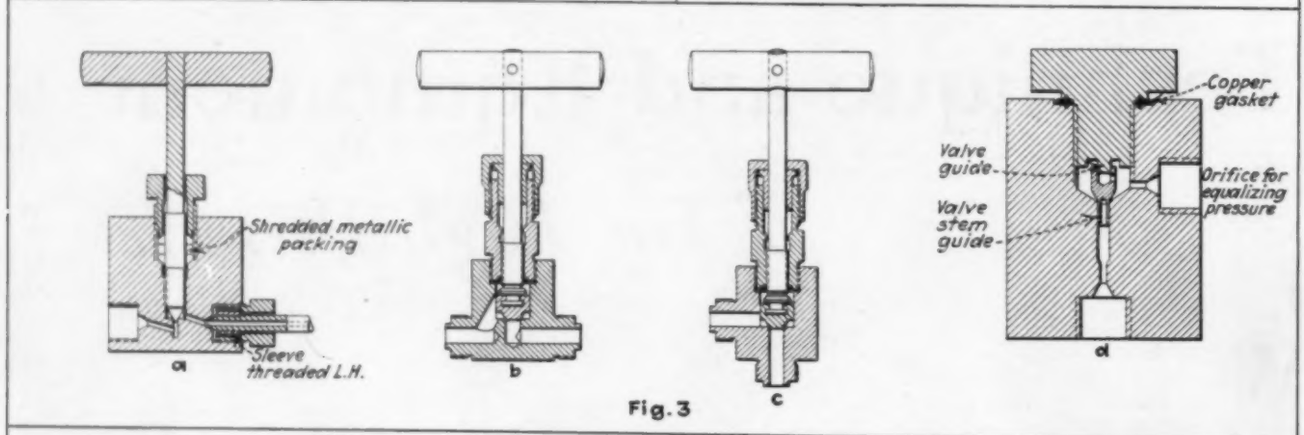


Fig. 3

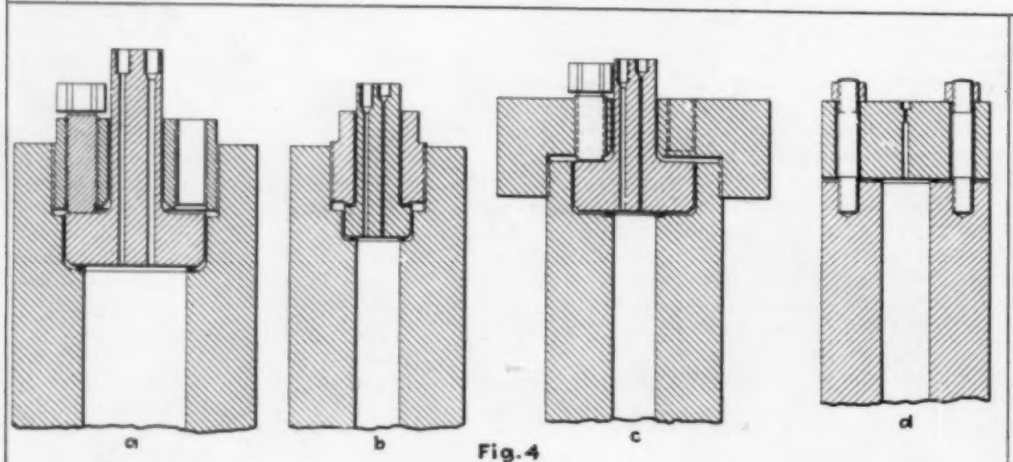


Fig. 4

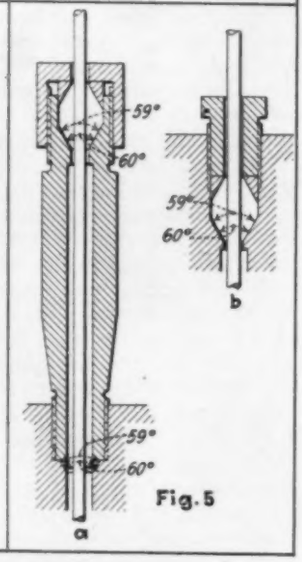


Fig. 5

Tubing Joints, Valves, Heads, and Constructional Features in Pressure Work

Fig. 1—End to End Joints, and Tubing to Valve and Body Joints Illustrated by Six Examples, Without Gaskets.

Fig. 2—Joining Pipe by Four Methods Involving Use of Copper-Plated Steel Gaskets Whose Design Depends on Pipe Diameter.

Fig. 3—Block, Line, and Angle Valves With Metallic Packing. Unusually Light Weight Is a Feature.

Fig. 4—Closing the Ends of Pressure Vessels Can Be Accomplished in at Least Four Ways Depending on Inside Diameter.

Fig. 5—Insulating and Sealing Electric Leads for Heaters and Temperature Measurement Using Compression Gasket.

ends of pipe or joining a pipe and a fitting where pressures up to approximately 1,500 lb. are used. These designs have been thoroughly tested, using copper-plated gaskets of soft steel. *A* is suitable for pipe about 8 in. in diameter where the gasket faces are rather narrow and the center of pressure in each case is about $\frac{1}{8}$ in. beyond the outside diameter of the pipe. *B* shows a copper-plated gasket which just fits within the bolts. *C* is a section through a step joint frequently used on boilers and superheaters, suitable for use with pipe approximately 3 or 4 in. in diameter. *D* is a pipe to fitting joint.

Valves—Fig. 3 illustrates three types of valves hand-operated and one check valve. The valve shown in *A* is made from a solid block of steel and may have any of the usual types of tubing connections. The value stem is a hardened cone making its own seat on the softer metal of the body. Shredded metallic packing is suitable in this case where the temperatures are low. The valve stem has a shoulder which prevents it from being blown out in case of cracking or shearing of the stem. *B* is a line valve with straightway connections, and *C* is an angle valve. Both of these have plugs which are hardened and make their seats in the softer body of the valve. These valves are considerably lighter in weight than most commercial designs available. *D* is a high pressure check valve the construction of which is obvious from the drawing. The valve and seat should be lapped, and an orifice for equalizing pressure is provided in the valve.

Heads—Fig. 4 illustrates four suggestions for closing the ends of high-pressure containers or vessels such as converter or catalyst tubes. In three cases the retaining bolts are in compression when under load, and the bolt circle is as nearly directly over the mean gasket diameter as possible. *A* is preferable, but for experimental work, where the inside diameters of the cylinders are small, it cannot always be used. *E* is perhaps a little more difficult to assemble than *C* but requires less space and is lighter and somewhat cheaper. It should not be used where the nut end would be across flats greater than about 4 in. Bolts as large as possible and practicable for the particular equipment should be used. In *A* the joint is made by placing the head in position on the gasket in the end of the cylinder. The retaining ring with interrupted thread is dropped into place and given sufficient rotation to engage the threads for their full length. The bolts are then screwed down until the joint is made tight. *B* is similar except that there is but one bolt, which is also the retaining ring. In this case the threads are not interrupted. The gaskets may be of copper, silver, or some other relatively soft metal which will actually flow under the pressure of the bolts, thus filling the small V-groove cut both in the seat of the cylinder and in the head.

In *A* the bolts are tapped into the heavy wall of the vessel, and care must be exercised in tightening down.

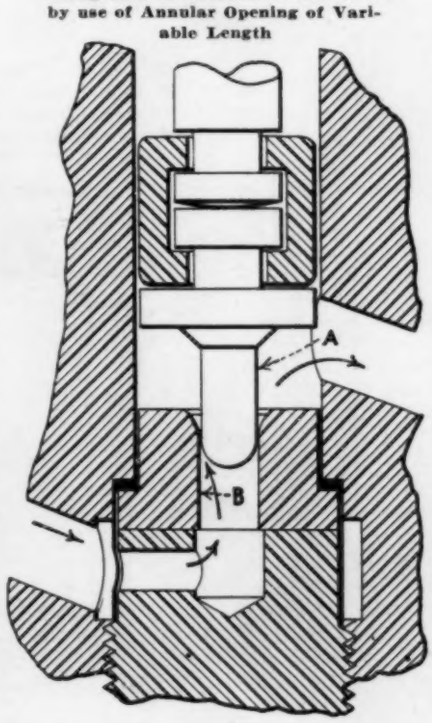
Electrical Leads — It is frequently necessary to seal an electric lead into a pressure vessel. In Fig. 5, *A* and *B* show two methods of doing this. *A* is suitable where the space in the head of the vessel is limited and *B* where sufficient space can be used to make the connection directly. The insulating material is soapstone or Bakelite, which is cut as shown into double-ended truncated cones with the contained angle of the cone less than 60 deg.; preferably 59 or even 58 deg. The seat and follower ring are cut to a 60-deg. angle. As pressure is applied by means of the gland, line contact is maintained. The electric lead may be centrally spaced in the hole or insulated to keep it out of contact with the steel of the vessel.

Flow Regulation at High Pressures

THIS DESCRIPTION of a valve for the exact regulation of gas and liquid flow under pressure is furnished by the Mathieson Alkali Works, Inc. It is well known that any valve operating in a "cracked" position —that is, open only a small fraction of a turn—is subject to rapid and excessive erosion of the seat and disk parts. Ordinarily, this is not particularly serious when handling low-pressure gases and liquids, as the velocity through the small openings is not great enough to affect seriously the valve parts in a reasonable length of time. When valves are used on high-pressure gas work (about 4,000 lb. per square inch) the velocity, due to the higher pressure, is very much greater and the eroding effect much more pronounced. Furthermore, a good valve for regulating purposes should show, when flows are plotted against "turns" on the valve stem, a more or less straight-line characteristic for all positions.

The average high-pressure valve with the 45-deg. ground joint type of seat does not have these properties. With a pressure drop several thousand pounds across the valve, a very small opening—i.e., a fraction of a turn on the stem—is sufficient to permit a relatively large volume of gas or liquid to pass through the valve, and the increments of opening are not even roughly proportional to the flow. The valve which is herein described was designed specifically for use in a synthetic-ammonia plant for bleeding off liquid ammonia at 4,500 lb. per square inch to the storage tanks, which are at a pressure of about 150 lb. per square inch.

Long Life Is Secured in this Valve by use of Annular Opening of Variable Length



The essential feature of this valve is in the design of the disk (*A*) and seat (*B*) parts. As shown on the drawing, the long straight pilot on the disk fits into a hole in the seat and the parts are ground and lapped together so that the annular space between the two pieces when assembled is very small—of the order of 0.0001 in. When the valve is first placed in operation, the pilot of the disk just enters the hole in the seat and the regulation takes place in about the position shown in the drawing. Both parts are made of hardened tool steel, but as time goes on, erosion takes place and the pilot of the disk gets smaller in diameter and the hole in the seat correspondingly larger. This wear is compensated for by causing the pilot to enter farther and farther into the seat. Even after considerable erosion has taken place, the regulation of the valve is not affected as the *length* of the annular space between pilot and seat compensates for the increased *space* through which the liquid flows. In effect, the design incorporates a valve having an annular opening in the seat variable in length.

When there are interruptions in production and it is necessary to shut the valve tightly, the pilot is screwed all the way in and the valve is closed by the contact of the auxiliary 45 deg. ground joint at the base of the pilot. When the pilot and seat parts have worn, the parts are removed and new parts are installed.

Adapting

Instrument Control

To High-Pressure Operation

EDITORIAL STAFF DISCUSSION

CONTROL INSTRUMENTATION in the high pressure industries has not reached the degree of refinement encountered in the low pressure field. In view of the newness of the industries and the fact that problems of greater moment have absorbed the attention of their engineers, it is not surprising that only the indispensable instruments have been applied in most cases. It is rather infrequent that this instrumentation has reached the stage of automatic control. In the high-temperature, low-pressure field, however, instrument control has fared much better since means of measurement at high temperatures have been available for a considerable period. It is also a fact that the difficulties attendant on instrumenting high temperature plants are much less stringent than those in high pressure processes.

Where measurements at high pressure are to be made, it has been necessary sometimes to develop totally new instruments. At best, there is a difficult problem in adapting existing instruments for high pressure uses. High temperatures, on the other hand, introduce only the necessity for suitable construction materials in contact with the process and these are readily available. Through use of the right material, almost any variable in a high temperature process may be readily controlled with otherwise standard apparatus.

Another factor which has militated against very extensive instrumentation in high pressure operations is the hazard which an instrument failure may present. Under such exceedingly severe conditions, the mortality of ordinarily reliable equipment is naturally higher, and there is a hesitancy on the part of the user to trust too much to instruments. He recognizes a certain minimum as indispensable, but does not feel secure in going beyond this. Greater reliability may undoubtedly be expected in the near future.

There are decided advantages in improved product, better operation, and less labor to be gained from sufficient use of control instruments. If a single instrument be too fallible, the hazard may be greatly reduced by duplicating the more important control equipment. It is highly improbable that two control thermometers would fail at the same time. More thorough supervision of the instruments is, of course, necessary in the high pressure plant, and the process cannot be permitted to run itself to the same extent as a low pressure operation. But a man who does not have to keep his hand on a valve can cover a great deal more territory than one who does. To make certain that he actually cover this territory, he could be required to keep frequent written records of variables as shown by indicating instruments. Recorders for the same variables would be out of sight in the superintendent's office, or elsewhere, not accessible to the operator.

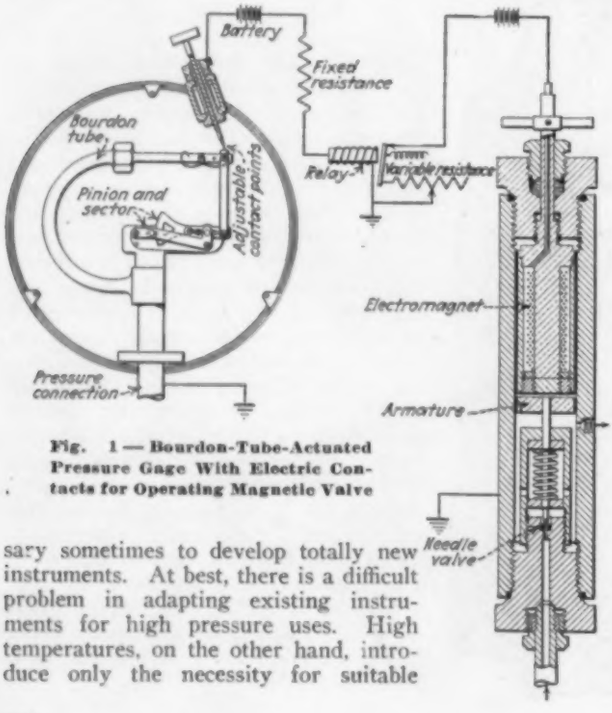


Fig. 1 — Bourdon-Tube-Actuated Pressure Gage With Electric Contacts for Operating Magnetic Valve

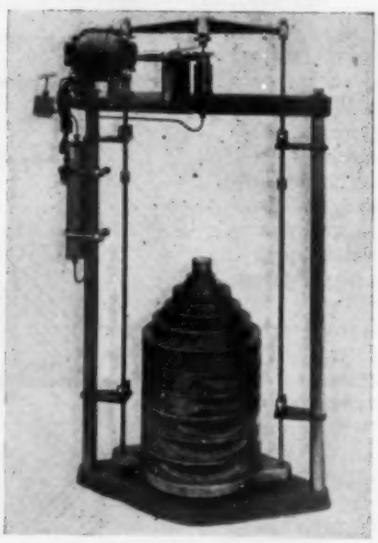


Fig. 2—Dead Weight Type of Pressure Gage, Most Accurate Construction for High-Pressure Measurement; the Ultimate Standard in Gage Checking

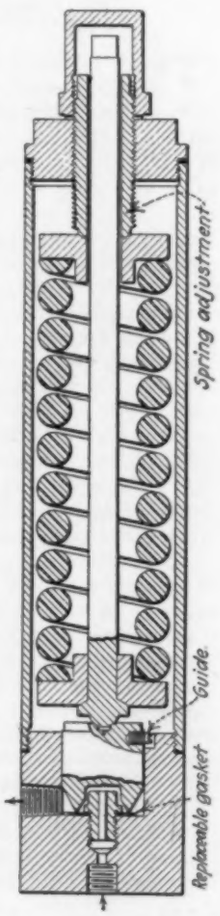


Fig. 3—This Type of High-Pressure Relief Valve, Developed at Fixed Nitrogen Research Laboratory, Closes Tight After Relieving Pressure

Usual Range of Temperature-Measuring Instruments

	Range, Deg. F.
Thermometers	to 1,800
Fluid expansion	−40 to 1,000
Liquid in glass	−40 to 1,000
Fluid in metal	−40 to 1,000
Liquid	−40 to 1,000
Vapor tension	+20 to 750
Gas	−40 to 1,000
Bimetallic expansion	to 600
Metallic—Non-metallic expansion	to 1,000
Resistance	approx. −330 to 1,800
Pyrometers	to 5,000
Pyrometric cones	1,900 to 3,700
Thermoelectric pyrometers, abs. zero, approx	to 3,000
Copper—Constantan	to 1,000
Nichrome—Constantan	to 1,600
Iron—Constantan	to 1,600
Chromel—Alumel	to 2,200
Platinum—(Platinum-Rhodium)	to 2,800*
Total radiation	1,000 to 3,600
Optical	1,400 to 5,000

* Intermittent use to 3,000 deg. F.

High-Temperature Operations — Of the various factors needing control in a high temperature plant, temperature itself is usually the most important, and it will be the only one included here. Control of pressure, speed, flow, etc., usually introduces only construction materials problems. Temperature measurement and control are fully covered by existing standard equipment. A summary of what is available and the range usually covered by each type is to be found in the accompanying tabulation.

High-Pressure Operations—Most important of the process variables to be controlled in the high pressure plant are temperature, pressure, flow, level, weight and gas analysis. Temperature measurement is perhaps least difficult since it is solved when a suitable thermometer well is developed. Thermometer wells are undoubtedly a vulnerable point for they must resist corrosion and collapse successfully and yet not introduce too great a time lag. Forged steel and alloy steel are usually specified. To reduce lag, forged steel thermometer bulbs, machined to a drive fit in the well, may be used. Or the well may be filled with a molten metal which fuses above the operating temperature and which has a coefficient of expansion such as to assist in resisting crushing stresses on the well. It might also be possible to seal a liquid, such as mercury or an oil, in the well by means of a stuffing box, and so reduce the required well thickness. In any event, frequent inspection and replacement of wells is a very desirable safety precaution. Well replacement should not await evidence of incipient failure.

Pressure—All high pressure operations require the measurement of pressure at numerous points. Generally in the chemical industries, dead weight and bourdon tube gages (and occasionally diaphragm gages) are used for this purpose, usually without recording mechanism. Bourdon tube gages (or diaphragm gages) are used for direct operation and dead weight gages for frequent checking of the former. In one plant this checking is accomplished in a very convenient manner. About a dozen gages placed at various points throughout the plant are joined by small-bore copper tubing to a central panel, where each in turn may be connected to the dead weight gage by opening a valve. Connections to the bourdon gages are made at a tee inserted below the oil seal in the line joining each gage to its piece of apparatus. A valve in the copper tube is opened only when testing.

Reports of difficulty with gages for these high pressures are somewhat frequent. This seems peculiar in view of the fact that the service demanded of gages on lead extrusion presses, homogenizers and some hydraulic pressing operations is even more severe, with pressures of 5,000 to 10,00 lb., and frequent pressure fluctuations of considerable magnitude. And yet, there are a large number of recording gages reported to be in successful operation in such cases. Some of these use helical tubes, instead of the conventional bourdon tube.

Bourdon tubes, which are most frequently the sensitive element in high pressure gages, are made of carefully selected round stock which is drilled out, flattened and bent to the shape shown in Fig. 1. The finished tube must be carefully seasoned before use. As shown in the drawing, the open end of the tube is anchored while the free

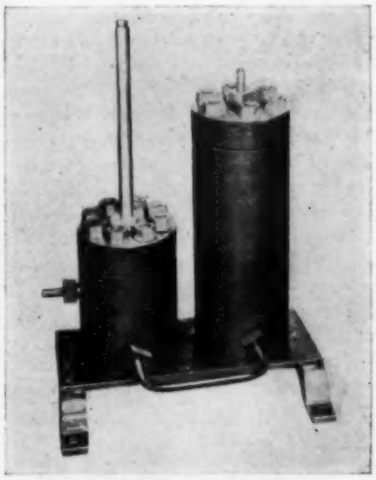


Fig. 4—Forged Steel High-Pressure Manometer Made by Brown; Inductance Bridge for Indicating Level in Instrument Fits Over Closed Pipe on Left Leg of U Tube

end operates the pointer through a toothed sector and pinion as pressure variations cause the free end to move. In a pressure reducer developed at the Fixed Nitrogen Research Laboratory (U. S. Department of Agriculture), electric contacts operated by the gage, as in the figure, control a magnetic valve through a relay. Construction of the valve is such that passage of current through the electromagnet opens the valve against a spring. Suppose pressure is being reduced from 300 to 200 atm. and the valve is open. The gage is on the low pressure side. When

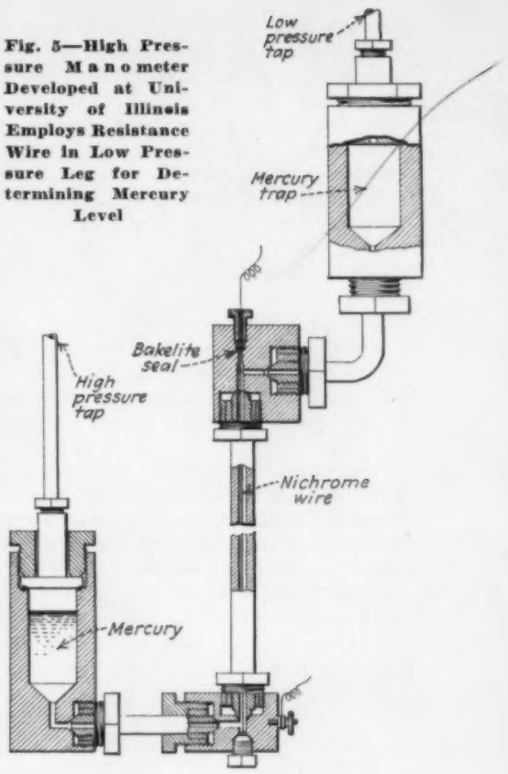


Fig. 5—High Pressure Manometer Developed at University of Illinois Employs Resistance Wire in Low Pressure Leg for Determining Mercury Level

the low pressure has climbed to 200 atm., the contact is closed by the gage, closing the relay and breaking the circuit through the magnetic valve. The valve closes and remains closed until the low pressure has fallen sufficiently to break the gage contact again.

This set-up, as illustrated, is made by the American Instrument Company, of Washington, and is understood to be available only in a laboratory and semi-works valve. Another application of the valve is in a bypass line between the suction and discharge of a compressor where it serves to maintain constant discharge pressure.

Dead weight gages are the final standard in all pressure gage testing. Since the advent of high pressures in the plant, the dead weight gage has assumed new importance, both as a laboratory instrument for extreme accuracy, and as a checking device for the plant. Recently developed dead weight gages differ from the older ones, used only for testing, principally in the nicety of the piston fit, the method of supporting the weights and in the addition of an automatic means for insuring complete freedom of the piston. In the gage shown in Fig. 2 (American Instrument Company), care is taken to prevent eccentric loading of the piston. The piston and pressure cylinder are mounted on the top frame with the weight-supporting yoke connected to the piston. An arm also connected to the piston is slowly oscillated back and forth by a pin attached to the motor-driven worm gear. This preserves the oil film and prevents the piston's sticking.

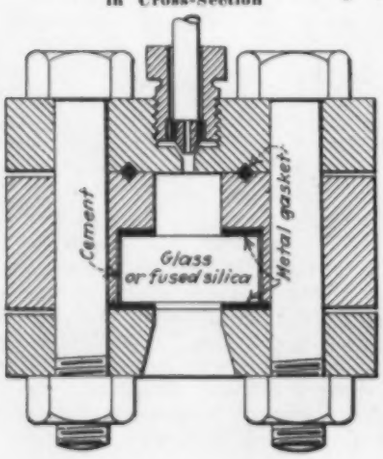
Safe operation of a high pressure plant requires automatic protection against excess pressures. The use of

rupture disks for this purpose is to be recommended on the score of low cost and certain action. But, should one of these disks let go, there is no way to stop the discharge until the pressure is completely dissipated. For this reason, relief valves should also be used, set at a lower pressure than the rupture pressure of the disks. Good practice, of course, requires that both valves and disks be located in the main body of the apparatus or near the point where excess pressure will first develop.

Relief valves are obtainable for use in the high pressure range but, according to reports, most of them will not close tightly once the excess pressure has been relieved. A valve developed by the Fixed Nitrogen Research Laboratory, and made commercially by the American Instrument Company, is said to overcome this difficulty (see Fig. 3), but is available in sizes sufficient only for laboratory, semi-works and small works-scale plants, for piping up to ¼ in. O.D. It has been suggested that regularly available relief valves may be used by employing two, one set to release at a slightly higher pressure than the other. Needle valves which could be securely locked in the open position would be placed between the apparatus and the relief valves and the keys intrusted to some responsible official. If then one valve should release, the needle valve would be closed (by the official) while the relief valve was reseated tightly. Meanwhile the second relief valve and the rupture disks would furnish sufficient protection for the system.

Flow—Measurement of flow is an important requirement of most high-pressure plants, especially where gases are recirculated. In this case it is also very necessary that a means of flow control should be available. Various methods for regulating flow rates have been developed which include: (1) the use of variable-speed motors to drive the compressors; (2) hydraulic transmissions on the compressor drives; (3) varying the compressor clearance by use of a retractable cylinder head; and (4) varying the compressor stroke. Compressors may also be steam driven, in which case speed control is simplified.

Fig. 6—Suggested Form of Gage Glass for High-Pressures Shown in Cross-Section



Of the methods suggested above, No. 4 is the only one that is not self-evident. This method is employed by a Swiss compressor manufacturer (see page 573, this issue) who uses what amounts to a hydraulic transmission with a variable cutoff for driving the last two compressor stages. In effect the delivery of this compressor is adjusted as in method 3 by changing the clearance, in addition to the change in the displacement.

The problem of measuring flow at high pressure appears to have been solved satisfactorily merely by increasing the strength of the manometers of standard orifice meters. Foxboro Company has introduced high-pressure manometers for 2,500 and 5,000 lb. pressure. (See *Chem. & Met.*, page 181, March, 1930.) This instrument uses a manometer of forged steel and a longer shaft seal. Similarly the Republic and Brown instruments (the latter, Fig. 4) are using heavy steel forgings, and since both of these are electrical, no difficulty in transmitting the manometer readings to the outside is encountered. (For description of the principles of these instruments, see *Chem. & Met.*, April, 1929, page 247.)

Still another type of electrical manometer has been developed by N. W. Krase in the high pressure laboratory at the University of Illinois. This is shown in Fig. 5. It consists of a U tube for mercury, formed of seamless alloy steel tubing and forged steel fittings. A Nichrome resistance wire extends through one leg of the tube where it is secured at the top by a Bakelite compression seal. The mercury, wire and tube comprise part of a circuit, the external portion of which includes a source of constant voltage and a variable resistance. Shunted across the Nichrome wire is a millivoltmeter for reading the flow in terms of mercury height. The instrument and orifice are calibrated together against actual gas delivery. Protection against blowing out the mercury is afforded by a trap in the low pressure leg of the U. Seals placed in the connecting pipes guard the mercury against contamination and have made it possible to hold the calibration of the instrument for a considerable period, how long is not yet known.

Level—Measurement of liquid level can be accomplished in several ways in high-pressure operations, only one or two of which are generally in use. Perhaps the most common is a variation of the ordinary gage cock. In the lower range, gage glasses of special design are used occasionally, but it is somewhat surprising that more effort has not been directed toward developing safe gage glasses for pressures as high as may be met. In high-pressure boiler plants, special glass tubes are to be found and also a new type of gage which offers interesting possibilities for chemical use. Fig. 6 suggests in cross-section a modification of the latter.

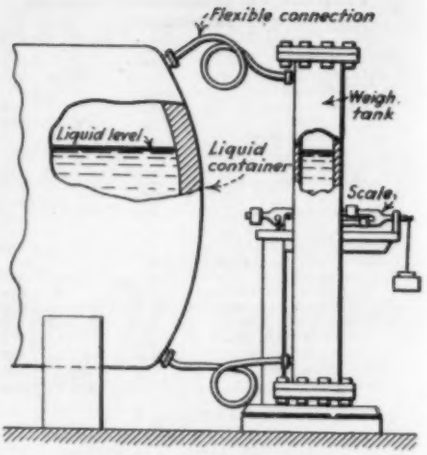


Fig. 7—Small Diameter Floating Weigh Tank, Joined by Flexible Tubing to Liquid Tank, Suggested for Measuring Level

High-pressure manometers, as described in the previous section, are very satisfactory for level measurement where the head is not so great as to make the manometer impracticably long. The high-pressure tap is simply connected to the bottom of the tank and the low-pressure tap above the liquid level.

A method for level measurement (Fig. 7) has recently been suggested which seems to be as safe and reliable as any that has come to our attention. This is a variation of the familiar device of weighing liquids under pressure in a floating tank placed on a scale. The weigh tank diameter should be made as small as possible, still keeping its volume sufficient to give the requisite weighing accuracy. The tank should be somewhat higher than the liquid to be measured. It is supported on a scale calibrated in terms of liquid height and connected top and bottom to the top and bottom of the apparatus to be measured, by small-bore tubing coiled to give sufficient flexibility. If necessary the tank may be counterweighted.

Weight measurement is almost universally solved in high-pressure processes through the use of a floating weigh tank. It is similar to Fig. 7 except that it is made as large as may be needed to weigh the greatest practicable amount of liquid at one time.

Gas Analysis ordinarily introduces no new problems since the gases are usually first expanded to low pressure. Analysis is then accomplished in a thermal conductivity cell; by means of an Orsat mechanical or otherwise; or by determination of density or viscosity (see pages 230, 249, *Chem. & Met.*, April, 1929). In one plant, however, it is understood that a mixture of two gases is being analyzed under high pressure by a variation of the Westphal balance. As the densities of the two gases are quite different, the method is said to be of considerable accuracy.

Transporting *Commodities Under Pressure*

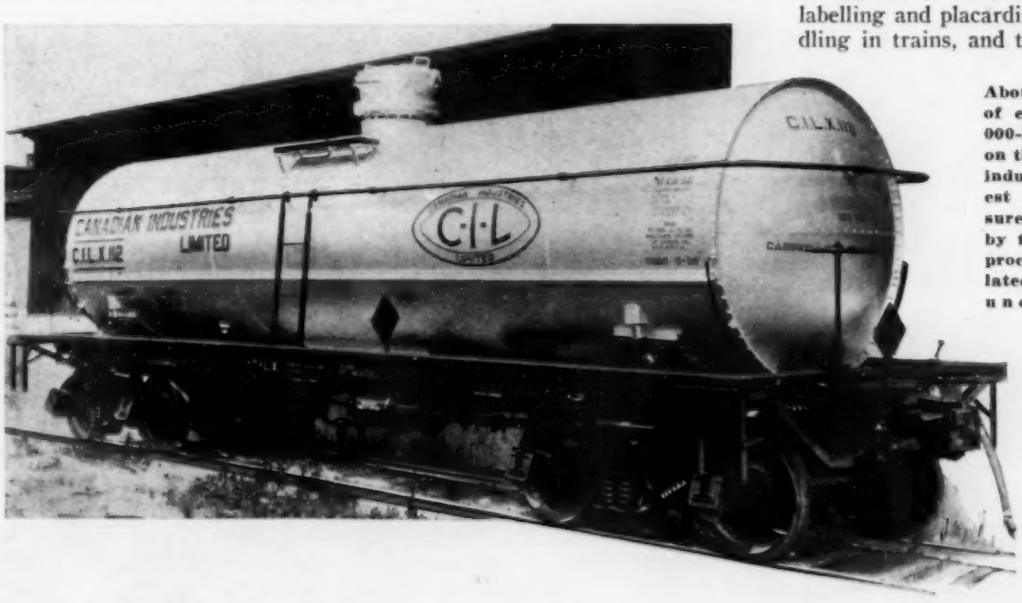
Labels for compressed gases must be diamond-shaped, 4 inches on each side, bright red for inflammable and bright green for non-inflammable gases, all conforming to standards shown above. Cars containing cylinders or packages with the red label and any tank car containing inflammable compressed gas must bear a large "Compressed Gas" placard

TRANSPORTATION of commodities under pressure has been essential to the development of many chemical engineering industries. Without proper containers and safe rules for their handling the compressed and liquefied gases which are today a large factor in the chemical industry could not be manufactured and marketed under the present efficient conditions. Under the wise supervision of the Interstate Commerce Commission and with the skilled co-operation of the Bureau of Explosives, the agency of the railways, the industry has prepared containers adequate for the handling of these commodities safely and efficiently.

For purposes of safe transportation the term "compressed gases" includes more than is usually indicated by the scientific meaning of this phrase. It includes, in addition to gases under pressure, also (*a*) any material which produces at 70 deg. F. a gage pressure in its container exceeding 25 lb. per square inch and (*b*) any liquid flammable material which has a vapor pressure exceeding, according to the season, 40 or 45 lb. per square inch at 100 deg. F. Thus in the group of "compressed gases" are included all of those light hydrocarbons and numerous other flammable liquids of high vapor tension, as well as any solids or liquids whose vapor pressure makes them equivalent for transportation purposes to a gas. However, the class does not include those highly poisonous materials known as "poison gases"; they are provided for in a separate part of the regulations particularly planned to cover safe handling of extremely toxic substances.

Shipment of any materials in the compressed gas group must be in metal cylinders, drums, or tank cars, built and tested in accordance with specifications of the I.C.C. The filling, way-billing, labelling and placarding, place and handling in trains, and the periodic retest-

Anhydrous ammonia is shipped in 50,000-lb. tank cars according to I.C.C. specifications. About 250 of these are now on the rails, and embody forge-welded tank with cork insulation



About 680 chlorine cars, of either 30,000 or 60,000-lb. capacity, are now on the rails, the chlorine industry being the oldest user of high-pressure tank cars. Built by the forge-lap welded process, they are insulated with 4 in. of cork under the protective jacket.

Authorized Transportation Containers

Cylinders, drums, and tank cars as indicated are authorized for shipping compressed and liquefied gases; older authorized forms which may still be used, but are no longer newly constructed for this use, are not shown. Where one container with marked pressure limit is authorized, any other of the same type and tested for *higher* pressure may also be used if desired.

No.	Commodity	Steel Cylinders																		Steel Drum	Riveted Lagged	Steel Tank Cars						Seamless	No.
		Seamless										Welded				Welded and Brazed						Welded Lagged				Welded			
		3A	3A150	3A300	3A480	3A1800	3B	3B150	3B300	3B480	3C	3D	3E	4	4A	4A150	4A300	4A480	4B	4B150	4B300	4B480	4C	8	5F	104A	105A300	105A400	105A500	105A600	106A 500	106A800	107A 3350	
1	Acetylene																							+									1
2	Anhydrous Ammonia				+									+				+						+			+						2
3	Blaugas					‡																											3
4	Carbon Dioxide (Liquefied)					‡							+																				4
5	Chlorine				+																						+				+		5
6	Ethylene					+																											6
7	Helium	+					+			+	+	+	+	+	+				+				+									+	7
8	Hydrogen Sulphide				+					+								+				+								+		+	8
9	Methyl chloride		+					+						‡		+				+							+				+			9
10	Monomethylamine			+										‡			+																	10
11	Nitrous Oxide				+									‡																				11
12	Propylene			‡					‡					‡			‡				‡													12
13	Sulphur Dioxide			‡					‡					‡			‡				‡						+				+			13
14	Nonliquefied gas (Pressure 250 lb. or less at 70 deg. F.)	+					+				+	+	+	+	+				+				+		+									14
15	Nonliquefied gas (not in solution or poisonous and not otherwise specified)	+					+				+	+	+	+	+				+				+		+									15
16	Liquefied gas (not in solution or poisonous and not otherwise specified)	‡					‡							‡	‡				‡															16
17	Liquefied Hydrocarbon Gas	‡					‡							‡	‡				‡							‡	‡	‡	‡	‡	‡	‡	‡		17
18	Liquefied Petroleum Gas	‡					‡							‡	‡				‡							‡	‡	‡	‡	‡	‡	‡	‡		18
19	Liquefied Petroleum Gas (Pressure 23 lb. at 70 deg. F. or 70 lb. at 130 deg. F.)	+					+				+			+	+				+				+		+	+	+	+	+	+	+	+		19
20	Liquefied Petroleum Gas (Pressure 70 lb. at 70 deg. F. or 145 lb. at 130 deg. F.)	+					+				+			+	+				+				+			+	+	+	+	+	+	+		20
21	Liquefied Petroleum Gas (Pressure 145 lb. or under at 130 deg. F.)	+					+				+			+	+				+				+			+	+	+	+	+	+	+		21

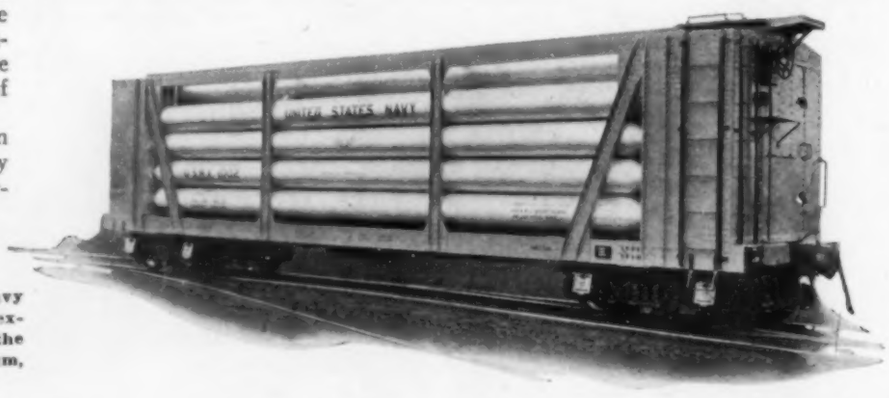
Permitted Filling Densities

To prevent overfilling with liquefied gases, the *maximum permitting filling densities* are prescribed as the ratios in percentages of the weight of "gas" in the container to the weight of the water which it will hold. To provide against excessive rise in pressure with temperature, it is required (for all gases except acetylene, carbon dioxide, and nitrous oxide) that at 130 deg. F. the pressure in a cylinder must not exceed one and one-quarter times the service pressure for which the cylinder is designed (at 70 deg). For tank-car shipments the gas pressure at 105 deg. F. in a lagged tank and at 130 deg. F. in an unlagged tank must not exceed three-fourths times the prescribed retest pressure for that style tank. Filling densities are limited, as are maximum total loads in tanks on a single car, to 600,000 lb.

Kind of Gas	Maximum Permitted Filling Density	Cylinders Required Marking	Tank Car Type Required
Ammonia Anhydrous	50 54 57	..... ICC-4; ICC-3A480; ICC-4A480; ICC-3	ICC-106A500 ..... ICC-105A300
Blau Gas	37	ICC-3A1800; ICC-3	.....
Carbon Dioxide, Liquefied	..	.....	.....
Chlorine	125	ICC-3A480; ICC-25; ICC-3	ICC-106A500; ICC-105A300
Ethylene	33	ICC-3A1800; ICC-3	.....
Helium	+	.....	ICC-107A3350
Hydrocarbon Gas, Liquefied	—	See remarks above	
Hydrogen Sulphide	68	ICC-3A480; ICC-3B480; ICC-4A480; ICC-4B480; ICC-26-480	ICC-106A800 ICC-105A600
Methyl Chloride	75	ICC-3A150; ICC-3B150; ICC-4A150; ICC-4B150; ICC-3; ICC-4; ICC-25; ICC-26-150; ICC-38	ICC-106A500 ICC-105A300
Monomethylamine	54	ICC-3A300; ICC-4A300; ICC-4; ICC-3	.....
Nitrous Oxide	68	ICC-3A1800; ICC-3	.....
Propylene	44	ICC-3A300; ICC-3B300; ICC-4A300; ICC-4B300; ICC-3; ICC-4; ICC-25; ICC-26-150; ICC-38	.....
Sulphur Dioxide	125	ICC-3A300; ICC-3B300; ICC-4A300; ICC-4B300; ICC-3; ICC-4; ICC-25; ICC-26-150; ICC-38	ICC-106A500 ICC-105A300

ing of containers are all fully prescribed. As a result of the precautions taken, the commodities which fall within this group, although inherently of considerable hazard, have proved to be entirely tractable members of society and are daily handled by the railroads and express companies of the nation with a negligible risk to anyone. The results obtained through the co-operation of the industry, the carriers, and the government officials has, indeed, been one of the most creditable in all of the history of transportation.

The photographs of tank cars shown on these pages were kindly supplied by the General American Tank Car Corporation.



New type of helium car built for U. S. Navy comprises 28 seamless-drawn cylinders. Flexibly lodged with special safety valves at the ends, they carry in all about a ton of helium, the whole car weighing over 100 tons.

Weldless Forged Steel Pressure Vessels

By JOHN L. COX

Assistant to the President
The Midvale Company
Nicetown, Philadelphia, Pa.

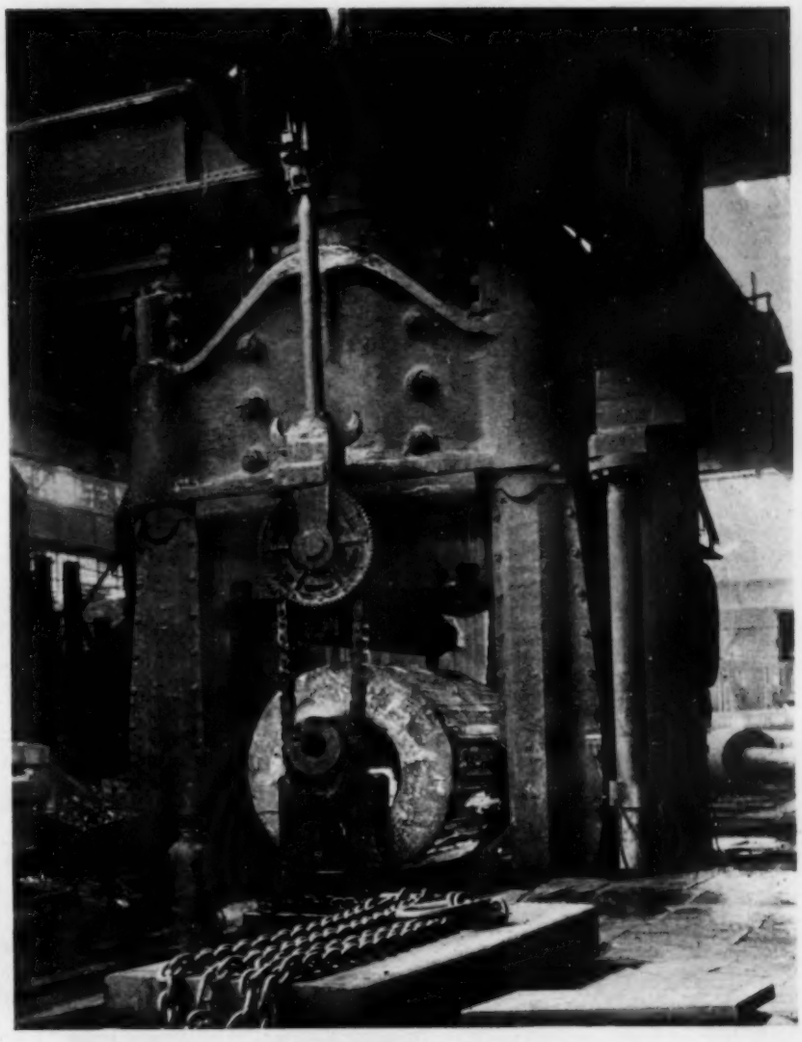
REQUIREMENTS of industry for vessels to withstand high pressures or high temperatures, or both, have led to a remarkable development in the construction of such equipment of a size and strength until recently unapproachable, and to the use in pressure vessels of alloy steels when necessary to secure special physical or chemical properties. Very satisfactory vessels with comparatively thin walls may be made by hammer or autogenous welding, but the strongest possible construction is the weldless cylinder.

Weldless vessels may be defined as those in which no part of the structural strength depends upon welded joints. It is not unusual for such vessels to have joints made tight by welding, or to have structural members so attached.

If of small inside diameter—up to about 20 in.—and if the wall is not too thick or the vessel too long, it may be made by cupping a circular plate of proper thickness under a press and drawing it out into a cylinder in a drawbench by passing it through successively smaller rings on mandrels of decreasing diameter, the method used by the National Tube Company for making 21-in. torpedo air flasks; or a billet of proper size and weight can be punched nearly through in a press, thus producing a thick-wall cylinder with a bottom integral head, and this cylinder can be forced through a series of rings of decreasing diameter in a drawbench on mandrels decreasing slightly in diameter for each series of rings.

If the expense of equipment is not justified by the size of the order, it is also possible to produce such cylinders by boring out a solid forging and turning the exterior to the desired outer diameter.

As cylinders above about 24 in. inside diameter involve too great a loss of metal if made by the method just described, a complete change of practice becomes necessary. This practice also is used for smaller cylinders under certain conditions. An ingot of the required composition and proper weight is cast with every precaution to secure well melted, sound steel. The ingot is reheated and a certain amount of scrap necessary to remove all unsoundness and excessive segregation of unavoidable impurities is cut from the top under a hydraulic press. The resulting block is reheated, upset, and punched to a diameter which will admit a stiff mandrel bar on which the hole can be enlarged. Hung on this bar, which is supported at each end of the block on the bottom crosshead of the press, the walls of the billet are thinned by successive squeezes of the press, the billet being revolved through a small angle between squeezes. As the walls become thinner the bore rapidly increases in size until it will freely admit the long, slightly tapered bar, called a mandrel, on which it is to be forged to diameter and length. Placed on this mandrel in a bottom Vee die, the top

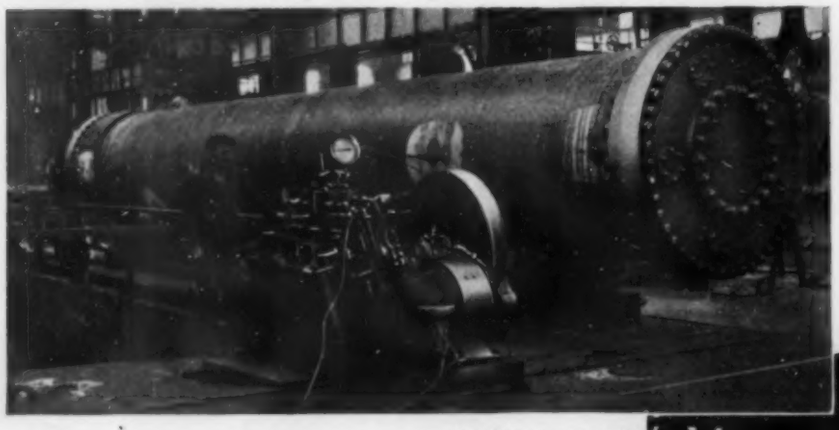


Walls of the Billet Are Thinned by Successive Squeezes of the Press

die of the press completing a pressure triangle, the walls of the expanded billet are reduced in thickness, the forging growing in length until the desired outer diameter is reached, the diameter of the mandrel controlling the inside diameter of the cylinder. Enlargements of the outer diameter are left at each end to provide anchorage for the cylinder heads if they are to be bolted on.

If no further forging is to be done the cylinder is annealed at this stage, and it is often given a preliminary annealing before further hot work. The cylinder is then machined inside and out, if this be required, and the excess metal on the outside is cut into a flange, if through bolts connect the head and body; or is contoured for stud bolts, or is rough-machined to a shape

Weldless Forged Steel Refinery Soaking Drum 35.5 Ft. Long, Weighing 271,000 Lb.



A Test of 1.5 Times the Working Pressure Is Used After Critical Inspection

which calculation and experience show will give the desired disposition of metal after the ends have been closed-in.

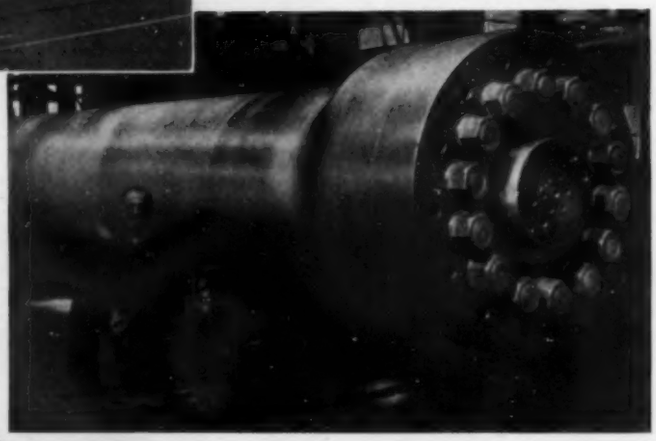
For the operation of forming integral heads each end of the cylinder is heated and by suitable dies is gently closed-in, according to templet or dimensions, until the desired shape and diameter are reached.

The cylinder then receives its final annealing, has its ends machined for the desired closure, has any necessary fittings attached, is subjected to a critical inspection, and finally to a pressure test, which is usually 1.5 times the working pressure, if the operating temperature is low, or to such higher pressure as may be required to simulate, cold, the relative figures for pressure and hot strength of metal at the actual temperature of operation.

Catalyst chambers generally require a full-size access to the interior, and the heads are attached by flange or stud bolts, or by a screw thread, usually cut in the inner wall of the cylinder.

The chemical composition of the steel employed depends upon the conditions of service as regards pressure, temperature, and chemical attack. When sufficient strength can be obtained without the use of alloys, and no chemical is involved, a simple carbon steel is always employed. Although for certain forms of chemical attack specific alloys are available which can be produced in ingots of any desired size, many of the resistant compositions can be made only in the electric furnace and successfully cast only in ingots of moderate size.

In carbon steel it is now possible to produce forged weldless cylinders up to 6 ft. internal diameter, and of the maximum weight that can be obtained from an ingot of about 225 tons. Obviously the length is dependent upon the weight of the cross-section involved.



Alloy Steel Cylinder for 40,000 Lb. per Square Inch Working Pressure

Chrome - Nickel - Molybdenum Steel Cylinder for 125,000 Lb. per Square Inch Pressure

With a given internal diameter the walls of a vessel must be made increasingly thick to withstand increased pressure, the steel must be fully heat treated, or use made of the higher properties of alloy steels. When the wall thickness exceeds 50 per cent of the internal diameter there is little strength to be gained by increasing the thickness, and practically none if the figure is 60 per cent.

Ferrous Metals

To Resist High Temperatures

By JAMES A. LEE

Assistant Editor, Chem. & Met.

BEFORE the World War, iron, steel, and refractories were the only available materials for equipment construction suitable for use at high temperatures in the process industries. The brittleness of refractories prevented extensive use of them; consequently iron and steel were used in enormous quantities, in spite of poor chemical and physical properties, which were responsible for their short period of usefulness.

It was first realized about 25 years ago that high-alloy steels possessed greater strength and resistance to scaling at high temperatures than did plain steels, but the most important developments in these materials have taken place during the past decade. By using alloys, alloy cast irons, low-alloy steels, or high-alloy steels in which there has been developed some special property or combination of properties, it is possible to secure resistance at high temperatures not obtainable in other materials. And the results of recent investigations serve to show the possibilities of developing a still further improvement in steels and alloys by the addition of other elements so that considerable advances in materials for use at high temperatures may be anticipated.

Cast irons, perhaps, have been in use longer for high-temperature service than any other metallic materials. They can be used where there are low pressures, up to 400 to 500 deg. F., or even higher. In the absence of pressure, cast iron can be utilized up to a red heat.

Recently the alloy cast irons have come into favor with chemical engineers for use at elevated temperatures. Since deterioration increases almost proportionally with increasing silicon content, irons low in the quantity of this element are more in demand. J. S. Vanick (*Chem. & Met.* 36, 1929, 537) points out that the carbide-forming elements, chromium, manganese, tungsten, molybdenum, vanadium, and the like, would retard the decomposition of cast irons by resisting the expulsion of dissolved carbon. Among these elements chromium seems to possess the greatest resistance to oxidation, and is most used. Its tendency to cause chill spots and prevent machinability, limits its quantity to 0.30 per cent or less, but this quantity can be doubled frequently if the chromium is accompanied by nickel additions, which preserve the dense, gray structure, disperse the chill, and restore machinability. Centrifugal pump castings, containing 3 per cent of nickel with 0.75 to 1 per cent of chromium and handling hot caustic, are reported to show a marked improvement over plain cast-iron pumps.

Among the ferrous materials for moderate temperatures— up to 700 deg. F.—carbon steels are still most important in castings, although their load-carrying ability is not satisfactory for service above about 550 deg. F. As the temperature of these steels is increased above 500 deg. F., the strength decreases rapidly. Plain carbon steels are often used in steam generating stations and oil refineries.

Due to the low load-carrying ability at higher temperatures the plain steels have given way to forged carbon steels or low-alloy steels, either cast or forged. Jerome Strauss reports (*Chem. & Met.*, 36, 1929, 535) that some of the low-alloy steels possess at moderately elevated temperatures — up to about 1,200 deg. F.—resistance to deformation as good as that of many of the costlier steels accompanied by sufficient resistance to some corrosive mediums to make them exceedingly desirable construction materials. A large production of valve bodies and valve parts, such as spindles and bolts, has been made from steels containing 1 to 1.5 per cent of nickel and 0.5 to 0.75 per cent of chromium.

A STEEL containing 1.75 to 2.25 per cent of nickel, 0.7 to 0.9 per cent of chromium, and 0.3 to 0.35 per cent of carbon is reported to resist satisfactorily temperatures between 750 and 1,100 deg. F. The safe creep stress for this alloy steel is from 70 to 100 per cent greater than that of plain carbon steel. Consequently, it will give a much greater factor of safety than carbon steel, in the same design of valves or fittings.

For these same classes of service, a chrome-vanadium steel containing 1 to 1.5 per cent of chromium and 0.2 per cent of vanadium also has been eminently successful, according to the same authority, not only because of exceptional strength properties at the moderately elevated temperatures employed but due as well to its having withstood satisfactorily the accompanying moderately corrosive conditions. The same steel, because of its ease of welding, casting, and forging, is used in the production of large hollow vessels, and because of its strength and corrosion resistance, is one of the most important steels for use for constructing reaction chambers for the synthetic-ammonia and the petroleum refining industries. Thus these low-alloy steels offer an excellent and relatively inexpensive material of construction for moderately high temperatures.

Intermediate alloy steels are increasing in importance as a material of construction for equipment in the process industries. A 5 to 6 per cent chromium steel with or without vanadium is used for resisting milder corrosion at moderate temperatures in the petroleum-refining industry. A 1 to 4 per cent tungsten, 0.5 to 2 per cent chromium, 0.25 per cent vanadium steel is reported to be successfully used at temperatures as high as 1,800 to 2,200 deg. F. for steam-generating equipment. Medium-manganese steels with a small addition of chromium offer good prospects for manufacturing seamless vessels to resist high pressures and temperatures in the heavy chemical, petroleum refining, and other process industries.

IT HAS been estimated that approximately ten million dollars is invested in high-chromium steels by the process industries. These steels, when properly annealed and worked, will stand much abuse. They are used principally for their resistance to oxidation at moderately elevated temperatures, to sulphur compounds at high temperatures, and to attack by nitric acid. Because of the resistance to hot sulphur they serve satisfactorily in the roasting of sulphide ores and in the petroleum-refining industry. Such steels have excellent load-

carrying ability at moderately elevated temperatures, but above 1,400 deg. F., are inferior to the high nickel-chromium alloys or the high-nickel high-chromium steels.

High-chromium low-carbon steels resist attack by nitric acid in any concentration up to the boiling point, and the gaseous products of ammonia oxidation at temperatures up to 1,300 deg. F. Most of the nitric-acid plants in this country are using this steel in enormous quantities for castings, piping, tanks, and absorption towers. These stainless steels have been used also by the chemical industries for valve parts, for high-pressure steam lines, for pump plungers, and for ammonia-synthesis compressors.

STAINLESS IRON—12-15 per cent chromium with carbon under 0.12 per cent—while lacking the highest corrosion resistance, finds many uses in the heavy chemical and petroleum-refining industries, and is used satisfactorily for nitric-acid equipment where the more concentrated acids are handled. Its physical properties make it suitable for bolts, nuts, and studs, which must be immune to attack by the acids. According to Walter M. Mitchell (*Chem. & Met.* 36, 1929, p. 533) this ferrous alloy retains its load-carrying ability excellently at elevated temperatures and will resist oxidation at temperatures below 1,500 deg. F. Stainless irons, with or without small additions of other elements, such as silicon, copper, or molybdenum, require care in handling, and excessive temperatures should be avoided, because of the tendency toward grain growth with loss of ductility, and impact strength.

MacQuigg (*Trans. Am. Inst. Chem. Eng.*, 1926) shows that resistance to oxidation and scaling increases with the chromium content, reaching a maximum at about 20 to 22 per cent of this element, and that steels of this analysis can be used at temperatures as high as 2,100 deg. F. for long periods without deterioration from scaling. Chrome irons—ferrous alloys containing a minimum of 20 per cent of chromium—are used chiefly in heat-resistant castings, such as for furnace parts. Owing to the tendency to grain growth and impairment of physical properties, these ferrous alloys are not always satisfactory for use where stresses are to be held at high temperatures.

Addition of nickel to chromium alloys and steels greatly improves their resistance to oxidation and chemical attack, as well as their load-carrying ability. Above 1,300 deg. F., the high-nickel high-chromium steels are stronger than any other of the ferrous alloys and are therefore better suited as materials of construction for heavily loaded equipment at these temperatures. In general these steels are a superior class of materials for chemical and mechanical stability at high temperatures.

Perhaps the alloy having the nominal composition of 18 per cent of chromium and 8 per cent of nickel is the best known of the high-chromium high-nickel steels. At 1,000 deg. F., its load-carrying ability is low; it cannot compete with some of the other alloys in castings for service where high resistance to flow is essential, but it is attractive on account of its excellent resistance to scaling and because of its comparative ease of fabrication. The low resistance to flow of this important material can be improved by modifications in heat-treatment and by varying the proportions of the constituents, silicon, carbon and molybdenum.

A decade ago, pressures in the refinery cracking stills seldom exceeded 100 lb. per square inch, but since then operating pressures have increased steadily and now are found to be as high as 1,000 lb., with temperatures approaching 1,000 deg. F. An "18-8" steel has been found to be more serviceable for tubes and cracking coils than any material previously used. During the current year approximately 5,000 tons of these steels will be put into service for these purposes in the oil refineries. A much larger application for these steels, just around the corner, is the fabrication of equipment suitable to withstand the pressures in excess of 200 atm. at temperatures of 750 to 950 deg. F. required in the recently developed process for catalytic hydrogenation of petroleum. It is reported that in the first commercial plant now being put into operation some of the largest ingot forgings ever produced of alloy steel are being used. In this plant the handling of hydrogen and the hot gases under such pressures and temperatures is in itself an exceedingly difficult problem.

Another new series of ferrous alloys of considerable importance are the high-chromium high-nickel high-silicon steels, which can be considered as satisfactory for occasional use up to 1,800 deg. F. at least, but probably could not be recommended for constant use at that temperature.

IN A paper presented before the Iron and Steel Institute, W. Rosenbain and C. H. Jenkins reported that some of the complex nickel-chromium-iron casting alloys containing elements such as carbon, silicon, tungsten, titanium, or molybdenum, possessed markedly improved mechanical properties. These authorities also stated that it is likely that considerable further advance in the production of alloys of still higher strength at high temperatures under prolonged loading is possible if a more extensive systematic investigation be undertaken.

F. M. Becket recently announced the results of his investigations of chromium-manganese steels. He found that steels containing more than about 16 per cent of chromium are markedly changed by increasing additions of manganese. About 6 per cent of the latter material changes the physical characteristics of chromium steels, increasing the strength, toughness, and deep drawing properties. In steels subjected to long-time exposure at high temperatures a minimum chromium content of at least 20 per cent is required for best results.

This investigation has included chromium-manganese steel to which several metals have been added—tungsten, molybdenum, copper, and others. Cobalt and tungsten additions have advantageous effects on the physical properties at high temperatures and stainlessness is not diminished by these additions.

Non-ferrous alloys, though they have certain fields of application in high temperature work, are used to a limited extent at medium-elevated temperatures—up to 1,000 deg. F.—on account of their cost. Eliminating the iron entirely results in alloys which probably are the most resistant to oxidation of any available. These iron-free nickel-chromium alloys are chiefly for high-temperature service and show excellent resistance to oxidation up to 1,800 to 2,000 deg. F., although in mechanical properties at these temperatures they are excelled by many high-alloy steels. It has been suggested that a practical solution of the problem of obtaining higher resistance to flow at these very high temperatures would be in addition of other elements to the alloys containing 60 to 65 per cent of nickel, and 10 to 20 per cent of chromium. Tungsten is one of the additions used industrially for this purpose.

A 60 TO 62 per cent nickel and 12 to 14 per cent chromium alloy in cast form is used for salt pots for annealing, for rolls in the production of the finer types of plate glass, for numerous parts of equipment in the vitreous enamel industry, for carburizing containers, including retorts, pots, and boxes. The "80-20" alloy is employed as the resistor material in modern forms of electric heat-treatment furnaces, skids, stack valves, rollers, and ever continuous chain belts. Other interesting applications of alloys of this group are the production of sodium cyanide from cyanamid, and for rotary muffle furnaces for making lithopone.

In general, it is true that the cost of any alloy or steel resulting from the use of expensive metals in large proportions will increase with increasing resistance to creep at high temperatures. Consequently, each type of alloy is only likely to be used where cheaper materials will fail. It might be worth while to emphasize the fact, which may not be generally known or appreciated, that no one alloy or steel is best for all purposes. And, of course, it should be remembered that in choosing a material it must be one that can be fabricated into the equipment desired.

Super-Refractories *for* Higher Temperatures

HIGHER TEMPERATURES are a natural corollary of higher pressures in many chemical engineering applications. For example, in cracking petroleum distillates, the generation of high-pressure steam, and in many chemical syntheses, pressures are often obtained directly as a result of heating. To carry forward these developments to their present successful status, the chemical engineer has demanded refractories that could withstand temperatures far beyond the standard range of fireclay and similar materials.

Obviously no single refractory can meet all the demands of the chemical engineer in high temperature and pressure applications. Certain general requirements, such as high softening point, mechanical strength at elevated temperatures, chemical inertness, resistance to great and sudden changes in temperature and pressure, are common to most applications. On the other hand, local conditions may demand other properties or emphasize one of the above at the expense of others. In the short articles that follow, an attempt has been made to summarize recent developments, with the special requirements of the chemical engineer in mind.

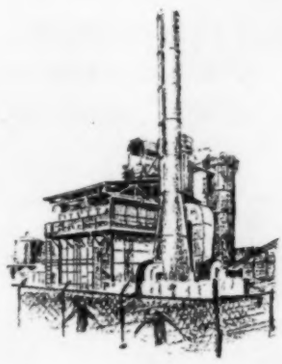
Zircon, Magnesia, and Chrome-Silica

By H. M. KRANER

Superintendent, Derry Works, Westinghouse Electric & Manufacturing Company, Derry, Pa.

ONE OF THE MOST notable developments in refractories for special melting operations is the utilization of the minerals zircon and zirconia. It is recognized that zirconia is difficult to form and fire satisfactorily, in view of an apparent volume change during cooling. Both zircon and zirconia are extremely refractory and it has been possible to utilize these refractories by the development of a suitable bonding material. These materials are now available not only in crucible form but also as commercial sized brick. The zircon material, especially, is very resistant to thermal shock and, therefore, withstands sudden heating and cooling in periodic, intermittent operations requiring rapid heating and cooling. This is especially desirable in electric induction furnace operation. Zircon is an acid refractory and is, therefore, not particularly resistant to the action of alkaline slags or iron oxide. It has been found, however, that several bonding materials can be used to increase its resistance to the action of these materials at high temperature and the refractory that results is very valuable in view of its high refractoriness, and its resistance to spalling.

Magnesia refractories usually have been considered the most resistant to the action of alkaline slags and iron oxide. They do not, however, withstand sudden heating and cooling as would be desired. There have been several recent and notable developments resulting in an



improvement in the resistance to spalling. This appears to have been accomplished by a study of the mineral structure developed in these refractories during use, and the development of bonds from such studies. Some of the best of these refractories use a very high grade of magnesia which has been electrically sintered, ground, and bonded with this special bond. Another development toward a magnesia refractory having high spalling resistance is the utilization of dolomite from which most of the lime has been extracted. These magnesia refractories will be of inestimable value in the many metallurgical applications.

Another recent development in refractories is the use of a combination of chromium oxide and silica. Chromium refractories are not particularly resistant to load at high temperatures, but will suitably resist alkaline and acid slags. Silica bricks are not resistant to spalling action, but are fairly refractory and withstand load almost perfectly up to their softening temperature. A combination of these two bricks has resulted in the production of one which seems to combine the two properties of high load bearing ability and refractoriness with improved slag resistance.

High Alumina, Magnesite, and Chrome Refractories

By WILLIAM F. ROCHOW

Harbison-Walker Refractories Company, Pittsburgh, Pa.

WHILE for many years high-alumina brick have been manufactured in relatively limited quantities for special applications, it is but comparatively recently that the production of these refractories has assumed important proportions.

At present, refractories of the alumina type are manufactured chiefly from diaspore, a high-alumina mineral; from crystalline alumina, prepared by the electric-furnace fusion of selected bauxite ore; and, to a lesser extent, from several alumina-silica minerals. Brick are being produced on a large scale in various classes of alumina content, including 50, 60, 70, and 80 per cent Al_2O_3 as compared with about 38 to 43 per cent Al_2O_3 (or less) in first-quality clay firebrick. These refractories have certain definite advantages over fireclay brick, such as greater refractoriness; higher temperature of incipient vitrification, resulting in lower spalling tendency, particularly in the high-temperature range; improved mechanical strength under heat; increased resistance to chemical attack of certain types of corrosive slags and clinker; and greater stability of mineral constitution and constancy of volume.

Service conditions are frequently very severe in boiler furnaces, particularly when the fuel burned is coal of low ash-fusion point, oil or acid sludge, petroleum coke, or hogged fuel. In such installations the use of high-alumina brick is becoming increasingly general because of their high refractoriness and

Rotary Cement Kilns Lined With High-Alumina Brick in Burning Zone

superiority in resistance to slag attack.

High-alumina refractories are being used for lining the burning zone of a majority of rotary kilns, including kilns for clinkering portland cement; for calcining dolomite and lime, and for reburning lime sludges in the paper and chemical industries. In making clay products alumina refractories find application in the fireboxes and arches of periodic kilns and in the firing zone of kilns operating at high temperature.

In the past, it has not always been possible to take full advantage of the exceptional resistance of magnesite and chrome refractories to chemical attack by basic slags, in processes where rapid temperature changes caused spalling of the brick. This limitation has been modified to an appreciable extent by recent improvements in the manufacturing operations, which have made practicable the use of magnesite and chrome brick under more severe conditions.

Extensive improvements have also been effected in the manufacture of silica and clay firebrick. These improvements include closer supervision of the mining and selection of raw materials; more accurate control of mixes, sizing, and moisture addition; the adoption of mechanical presses, resulting in improved workmanship; the use of continuous kilns; and complete laboratory supervision of all manufacturing operations.

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Mullite Refractories in Oil Refining

By T. S. CURTIS

Vice-President in Charge of Research
Vitrefrax Corporation,
Los Angeles, Calif.

DURING the past five years, the use of mullite refractories in the oil refineries of the Southwest has steadily increased until today nearly every major oil company in the Los Angeles area is specifying such brick as the standard for not only the most severe zones but, because of the remarkable physical stability of the refractory, for the large structures which are limited in life only by the irregular expansion of clay brick containing substantial percentages of free silica.

An outstanding application is that of linings for the huge sludge oil incinerators, wherein mullite brick have outlasted all other material for several years. The acid-sludge disposal problem carries with it a severe task for refractories, but this responsibility is well taken by brick of 72 per cent or higher mullite composition, and of the correct structure.

In general, the consensus among oil-refinery operators seems to be that the mullite refractory is well worth its higher cost by virtue of the vastly increased factor of safety made possible through its use. This opinion is backed up by the specifications of this type of brick in zones where the temperature is so low as to make possible the use of a second-quality firebrick but where mullite refractories have demonstrated their value in the reduction of repairs to previously unheard-of levels, due to the physical stability of the material.

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Glass Industry Perfects New Refractory

By FRED S. THOMPSON

Corhart Refractories Company,
Louisville, Ky.

THE IDEAL REFRACTORY for glass manufacture must not only be highly resistant to temperature but must be non-porous, to prevent the penetration of corrosive slags and glasses, resistant to load stress under heat, resistant to thermal shock, and of sufficient hardness to resist mechanical abrasion. This combination of low porosity and high fusion point has always been a difficult one to find. In many bodies when zero porosity is desired, refractoriness is sacrificed. When high refractoriness is desired, porosity must be sacrificed. A solution for the problem has come from the glass industry itself, by the development of a radically new process of manufacture.

Heretofore, the manufacture of refractory shapes, regardless of raw material used, has involved wet molding, drying, and burning. In the unique process developed first in the research laboratories of the Corning Glass Works, the refractory raw materials are melted in an electric furnace and the mobile liquid is poured into molds to form the finished shapes. Then after a thorough annealing the product is ready for shipment. This electrically cast refractory has all of the properties of the ideal body. Its P.C.E. (pyrometric cone equivalent) is cone 35 with no appreciable softening range ahead of that point. Its porosity is practically negligible, being less than ½ of 1 per cent. Under standard load test, its deflection is zero. It is harder than glass and will, therefore, resist mechanical abrasion.

Although originally developed and tried out for several years in the commercial glass melting furnaces of the Corning Glass Works, this company in conjunction with the Hartford Empire Company decided to manufacture the refractory and make it available to industry in general.

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Carbon and Graphite

CARBON, in a sense, is the ideal refractory. It does not melt or fuse at any temperature. Only when heated to such an extreme temperature as 3,500 deg. C. (6,332 deg. F.) does volatilization or sublimation take place. In using any form of carbon, however, there is always the necessity for avoiding oxidation. While no substantial oxidation or burning of either carbide or graphite occurs much below 500 deg. C. (932 deg. F.), at a bright red heat in an oxidizing atmosphere, carbon is rapidly consumed. It is also oxidized at high temperatures by fused oxides

Corhart Electrocast Corner Blocks (Light-Colored) in Use Two Years; Other Flux Refractories One Year

and by fluxes containing combined oxygen.

Carbon, as a refractory, is available as the bonded amorphous carbon, as the pure graphitic carbon such as electric furnace graphite, and as the bonded natural graphite. Amorphous carbon in the form of block, pipe, and various shapes is finding many new and interesting applications in chemical industry. One of the most recent to attract attention is the use of carbon tubes in Cottrell precipitators in acid recovery and manufacture. Furnace linings and slag floors in high-pressure boiler furnaces where pulverized coal is used, represent two other recent developments.

Electric furnace graphite is unique among refractories because of its purity, low linear expansion, and non-fusibility —all of which permit it to retain its shape, size, structure, and physical properties under conditions of extremely high temperature.

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Silicon Carbide and Fused Alumina

ELECTRICALLY fused alumina and silicon carbide, both products of the electric furnace, were originally produced because of valuable abrasive properties, but both are now widely used as refractory and heat-resisting materials. The general physical properties of fused alumina and silicon carbide, as well as of commercial refractories made from them by the Norton Company are as follows:

	Fused Alumina (Al_2O_3)	Silicon Carbide (SiC)
Melting point, deg. C.	2,050	diss. 2,250
Specific gravity	3.90–4.00	3.17–3.22
Specific heat	0.1827–0.20	0.186
	Alundum Refractories	**Crystolon Refractories**
Mod. of rupture, lb./sq.in.	2,100	3,200
Porosity, per cent	21	20
Bulk specific gravity	2.92	2.42
Load test deformation at 1,500 deg. C.–2,732 deg. F., 50 lb. per sq.in., per cent	2	None
Approx. weight 9-in. standard brick, lb.	11	9
Coefficient of expansion (c.g.s.)	0.0000050–65 0.00833	0.0000045 0.00982
Coefficient of expansion (c. g. s.)	Temp. interval 650–1,250 deg. C.	Temp. interval 730–1,188 deg. C.
Specific electrical resistance	1.8 megohms per cm. cu. 1,020 deg. C.	0.4 megohm per cm. cu. 1,040 deg. C.

The enameling industry uses alumina refractories in lining heavy-duty enameling furnaces. The ceramic industry has adopted the material for saggers. Lately both high alumina and silicon carbide refractories have been used to resist high temperatures in Venturi muffles and in the furnaces for tubular heaters in oil cracking operations.

Silicon carbide is extremely refractory, dissociating into graphite and silicon only at 2,250 deg. C., or 4,082 deg. F. and not melting. As an essential part of a refractory product or mixture, silicon carbide has valuable characteristics. It has great physical strength either hot or cold. It is an acidic material and is attacked at high temperatures by alkalis and iron oxide and strong basic materials but not by acids. Its ability to conduct heat is about six times that of ordinary fireclay.

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Ammonium Nitrate Production *Aided by Pressure*

By GIACOMO FAUSER

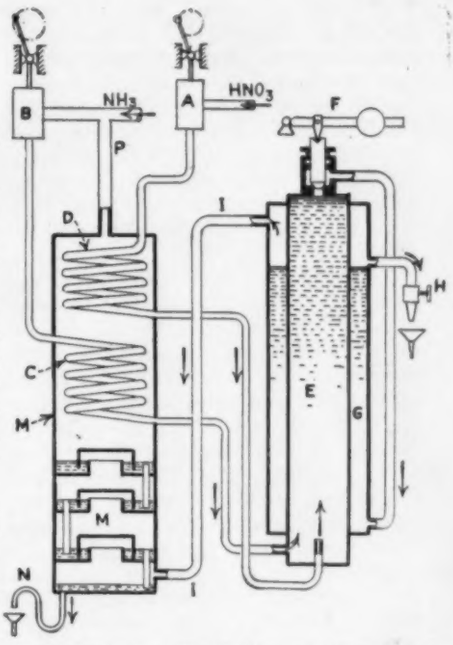
Industrial Engineer
Novara, Italy

UP to the present, preparation of ammonium nitrate has been conducted in apparatus that was constantly cooled to avoid any increase in the temperature of the reaction. The reason for this cooling lay in the fact that the boiling point of nitric acid is less than that of the ammonium nitrate solution obtained, wherefore it is not possible to utilize the heat of reaction in order to evaporate the mother liquor, as in the production of ammonium sulphate. Another reason is the fact that equipment is so easily attacked by solutions of boiling nitric acid.

But the elimination of the heat developed by the reaction of nitric acid and ammonia by means of water cooling is an irrational operation, because the ammonium nitrate solution obtained becomes very diluted; then it is necessary to obtain the salt by concentration of the solution, with the considerable consumption of about 1.5 k.g. of steam per kilogram of ammonium nitrate.

According to a new process, it is possible to use the heat of reaction for concentrating the ammonium nitrate solution. It amounts to causing a reaction of ammonia and nitric acid in a vessel under a pressure higher than corresponds to the boiling temperature of ammonium nitrate solution. The actual procedure becomes evident in the accompanying diagram. The nitric acid and ammonia are sent by the pumps *A* and *B* into the coils *C* and *D* to be heated by the steam from the concentration of the mother liquor. Then they are introduced into the saturator *E*, where the subsequent reaction raises the temperature to 170-180 deg. C. Here there is no release of ammoniacal or nitric vapors because the *pressure* of 8 to 9 atmospheres is higher than that of the boiling *temperature* in question. In order to avoid corrosion of the sides of the vessel, a slight excess of ammonia, according to stoichiometric proportions, is used to make the solution slightly alkaline.

The pressure within the chamber *E* is held constant by an automatic valve which permits the nitrate solution to discharge continuously into the exterior container *G*, which is at atmospheric



Equipment for Production of Ammonium Nitrate

pressure. Meanwhile the liquid in contact with the hot walls is brought to boiling and the concentrated solution is discharged at the orifice *H*, while the steam leaves at orifice *I* to go to the rectification column. The object of this column is to separate traces of ammonia entrained with the steam and at the same time preheat the nitric acid and ammonia on their way to the reaction. The residual water is discharged at siphon *N*, while the ammonia that has been recovered is led back to the compressor by the orifice *P*.

It is estimated that the economy resultant on this procedure by comparison with ordinary processes is at least $2 a ton of ammonium nitrate (35 per cent nitrogen). Considering the constantly increasing use of ammonium nitrate as fixed nitrogen, one can conceive that even a small reduction in the production cost allows a very large general economy. A complete description of this process, with calculations, thermal balance and technologic details, including cost of installation as well as of operation, will be presented before the International Congress of Applied Chemistry held in Liége in connection with the centenary celebration in the middle of this month.

High-Pressure Symposium Features A.C.S. Meeting

EDITORIAL STAFF REPORT

AN OUTSTANDING feature of the fall meeting of the American Chemical Society, held at Cincinnati, Ohio, Sept. 8 to 12, 1930, was the symposium on "Industrial High-Pressure Reactions." Held as a joint meeting of the divisions of Industrial and Engineering Chemistry, Petroleum, and Gas & Fuel, it met in the Library Building of the University of Cincinnati, under the chairmanship of Prof. Norman W. Krase, of the University of Illinois.

Nine papers were presented, two from government laboratories, one from industry, and six from university laboratories. Beginning with a brief introduction by Dr. Krase, the symposium opened at 2 p.m. with a paper by Drs. B. F. Smith and L. L. Hirst, of the Bureau of Mines Laboratory at Pittsburgh, entitled "The Reactions Which Occur on a Methanol Catalyst." It was shown that carbon dioxide and hydrogen react upon a mixed zinc oxide-chromium oxide catalyst at about 300 deg. C. to form methanol, carbon monoxide, and water. Likewise, carbon monoxide and water react to form carbon dioxide and hydrogen, and equilibrium can be closely approached in the water gas reaction. The possibility was suggested that the formation of methanol from carbon monoxide in hydrogen may not be direct, especially as a steady state is approached.

The second paper, given by Prof. B. F. Dodge and Dr. E. F. von Wettberg, reported work from the high-pressure laboratory at Yale University. The paper pointed out that in spite of all the published work on the subject, there are still some striking discrepancies to be cleared up in the methanol equilibrium. Some new experimental data attained by direct methods were presented. The constants agree fairly well at the lower temperatures with those obtained in the one published investigation by a direct method of one atmosphere and are considerably higher than those obtained in two investigations at higher pressures. The new data still leave an enormous gap between experimental and calculated results.

The third paper of the symposium, presented by Dr. P. H. Emmett and entitled "Studies on the Mechanism of Ammonia Synthesis Over Iron Catalysts," was a contribution from the Fixed Nitrogen Research Laboratory, of Washington, D. C. This paper summarized the enormous amount of work done by the Laboratory and considered the work of other investigators as well. In brief, measurements by various workers have shown that small but definite quantities of nitrogen, hydrogen, and ammonia are absorbed by pure or promoted iron ammonia catalysts, but there is no apparent relation between this adsorption and the activities of the catalysts. Results indicate the existence of iron atoms on the catalyst surface having much higher free energies than those in the lattice of massive iron. Calculations showed that nitrogen at a partial pressure of only a few atmospheres should be capable of reacting with surface iron atoms to form a nitride. The formation of such a nitride probably plays a part in the synthesis of ammonia from nitrogen-hydrogen mixtures over iron catalysts.

OF VERY great interest to all present was the contribution from the laboratories of the Standard Oil Development Company. This paper was presented by R. T. Haslam, having as co-author R. P. Russell, and entitled "Hydrogenation of Oils." Recent developments in the hydrogenation of petroleum, showing the adaptability of the process for converting fuel oil into gasoline and gas oil, increasing the parafinic nature of kerosenes, burning oils and lubricants were discussed. The reverse possibility of producing non-paraffinic gasolines also was discussed. Mr. Haslam pointed out the flexibility of the process, particularly with respect to changes in the characteristics of the product, the handling of a wide variety of charging stock, the elimination of all forms of sulphur and the conversion of all asphalts to distillate fuels.

The fifth paper of the afternoon was on "Condensation Reactions of Acetaldehyde Over Certain Oxide Catalysts at Pressures of From 1 to 500 Atm. of Hydrogen." The authors were Prof. Homer Adkins, Drs. M. E. Kinsey and K. Folkers. Description of apparatus for carrying out reactions between organic liquids under pressure in the vapor state in an atmosphere of hydrogen was given. The experimental work dealt with the effect of pressure, temperature, rate of flow, composition of catalyst, water contents, etc., on the ratio and rate of formation of hydrogen and ethylene, and with the effect of these variables on the character of the liquid products. These products are in all cases complicated mixtures. A list of compounds and yields was given together with equations suggesting probable mechanisms.

A paper by S. Swann, R. D. Snow, and D. B. Keyes, of the University of Illinois, entitled "Catalytic Hydration of Olefines," was presented by Dr. Keyes. This paper reported the study which had been made of the conditions for the catalytic hydration of olefines under pressure to alcohols. It was found that the equilibrium concentration of alcohol is small at pressures below 800 lb. per square inch. By increasing the concentration of halogen acid, the formation of alkyl halide is increased without apparently increasing the alcohol formation.

Two papers were from the laboratory of the Massachusetts Institute of Technology and were presented by Dr. Per K. Frolich. The first one, with Dr. D. S. Cryder, on "Catalysts for the Formation of Alcohols From Carbon Monoxide and Hydrogen," reported work continuing on the high-pressure synthesis of alcohols from mixtures of carbon monoxide and hydrogen. By studying the behavior under the conditions of high-pressure synthesis of the individual compounds which might be formed as intermediates, it has been possible to arrive at rather definite conclusions concerning mechanism. With methanol as an intermediate product, the higher alcohols are chiefly formed by successive condensations of lower ones.

The paper by Frolich and White was entitled "Adsorption of Methane and Hydrogen on Charcoal at High Pressures." This paper gave absorption isotherms of methane and hydrogen on charcoal over a pressure range of 1 to about 150 atm. and at temperatures of 25 deg. and 100 deg. C. The amount of gas absorbed increased markedly with pressure approaching a saturation value at 80 to 100 atm. Experiments with mixtures of methane and hydrogen under pressure of 25 deg. C. has shown that charcoal absorbs methane preferentially to the practically complete exclusion of hydrogen. The amount of methane absorbed is approximately equivalent to that which would be absorbed if the gas were present alone at a pressure equal to its partial pressure in the mixture.

THE ninth paper on the program, by Dr. B. H. Mackey and N. W. Krase, on the specific heats of gases at high pressures, was the third in this series and gave results for nitrogen to 150 deg. C. and 700 atm. The previous papers described methods and apparatus for measuring the specific heats of gases at ordinary and at elevated temperatures and at high pressures. The present paper gave results on the specific heat of nitrogen at 30 deg., 50 deg., 100 deg., 125 deg. and 150 deg. C. over the entire pressure range up to 700 atm. At all pressures, the specific heat of nitrogen decreases with temperature. At all temperatures the specific heat increases with pressures, the effect being greatest at the lower temperatures.

PATENTS ISSUED

Aug. 5 to Aug. 26, 1930

Paper, Pulp, Glass and Sugar

Method and Means for Making Crepe Paper. Harry Liebeck, Swarthmore, Pa., assignor to Scott Paper Company.—1,772,185.

Method of Treating and Utilizing the Black Liquor Obtained in the Soda-Pulp Process. Erik Hägglund, Abo, Finland.—1,772,216.

Apparatus for Producing Sheet Glass. Horace E. Allen, Toledo, Ohio, assignor to Libbey-Owens-Ford Glass Company, Toledo, Ohio.—1,772,448.

Production of Paper Pulp. Robert B. Wolf, New York, N. Y.—1,772,792.

Sugar Process. Rudolph E. Pospisil, Chippewa Falls, Wis., assignor of one-third to Edmund Kurek, Chippewa Falls, Wis.—1,772,911.

Process for the Production of Combinations of Rubber and Paper and Products Obtained Thereby. Reed P. Rose, Jackson Heights, and Harold E. Cude, Floral Park, N. Y., assignors to General Rubber Company, New York, N. Y.—1,773,201.

Fourdrinier Paper Machine. Herman L. Kutter, Hamilton, Ohio, assignor to Beloit Iron Works, Beloit, Wis.—1,773,270.

Process of Refining Alkaline Pulps. George A. Richter, Berlin, N. H., assignor to Brown Company, Berlin, N. H.—1,773,320.

Sulphite Wood Pulp and Method of Making the Same. Webster E. Byron Baker, Brooklyn, N. Y.—1,773,419.

Automatic Paper-Making Process and Apparatus. Melvin R. Ware, Plainfield, N. J.—1,773,832.

Method and Apparatus for Shredding and Drying Pulp. Ossian Anderson, Tumwater, Wash., assignor, by mesne assignments, to Puget Sound Pulp & Timber Company, Everett, Wash.—1,774,309.

Paper-Coating Mechanism and Process of Coating Paper. Luther A. Parker, Kalamazoo, Mich., assignor to the Champion Coated Paper Company, Hamilton, Ohio.—1,774,398.

Process of Producing Fiber of High Alpha Cellulose Content. George A. Richter, Berlin, N. H., assignor to Brown Company, Berlin, N. H.—1,774,403.

Rubber, Rayon and Plastics

Plastic-Casein Composition. Joseph G. Davidson, Yonkers, N. Y., and Ernest W. Reid, Pittsburgh, Pa., assignors to Carbide & Carbon Chemicals Corporation.—1,772,131.

Method for the Manufacture of Sea Caoutchouc. Charles Albert Houquesfourcade, Bordeaux, France.—1,772,218.

Composition of Matter and Method of Producing the Same. James F. Walsh, East Orange, and Harry E. Smith and Amerigo F. Caprio, Newark, N. J., assignors, by mesne assignments, to Celluloid Corporation.—1,772,529.

Method of Thickening and Stabilizing Latex and Product. Merwyn C. Teague, Jackson Heights, N. Y., assignor to American Rubber Company, East Cambridge, Mass.—1,772,647.

Preservation of Latex. John McGavack, Jackson Heights, N. Y., assignor to the Naugatuck Chemical Company, Naugatuck, Conn.—1,772,753.

Process of Vulcanizing Rubber. Winfield Scott, Nitro, W. Va., assignor to the Rubber Service Laboratories Co., Akron, Ohio.—1,773,379.

Method of Synthetic-Resin Manufacture. Emil E. Novotny, Logan, Pa., assignor to John Stogdell Stokes, Spring Valley Farms, Huntingdon Valley P. O., Pa.—1,773,598.

Yarn, Fabric, Plastic, Etc. Camille Dreyfus, New York, N. Y.—1,773,966.

Film. Carleton Ellis, Montclair, N. J.—1,773,974.

Process and Apparatus for Producing Dispersions. Chester R. MacDonald, Monroe, Mich., assignor to the Flintkote Company, Boston, Mass.—1,774,205.

Petroleum Refining and Products

Method of and Apparatus for Treating Hydrocarbons. Frank E. Wellman, Kansas City, Kan.—1,772,331.

Art of Cracking Hydrocarbon Oils. Eugene C. Herthel, Chicago, Ill., assignor to Sinclair Refining Company, New York, N. Y.—1,772,865.

Process for Purifying Hydrocarbon Oils. Jenö Tausz, Karlsruhe, Germany.—1,772,921.

Method of Sweetening Petroleum Hydrocarbons. Thaddeus W. Culmer, Robinson, Ill., assignor to Lincoln Oil Refining Company, Finlay, Ohio.—1,772,985.

Emulsion. Frederick W. Sullivan, Jr., Hammond, Ind., assignor to Standard Oil Company, Whiting, Ind.—1,773,123.

Art of Cracking Hydrocarbon Oils. Eugene C. Herthel and Thomas De Colon Tifft, Chicago, Ill., assignors to Sinclair Refining Company, New York, N. Y.—1,773,181.

Process for Breaking Petroleum Emulsions. Edwin E. Claytor, Tulsa, Okla., assignor to Petroleum Chemical Company, Tulsa, Okla.—1,773,517.

Apparatus for the Distillation of Solid Materials. Charles P. Tolman, Kew Gardens, N. Y., assignor, by mesne assignments, to Petroleum Conversion Corporation, New York, N. Y.—1,773,893.

Stable Mixture of Petroleum Hydrocarbons and Alcohols. Matthew D. Mann, Jr., Roselle, N. J.—1,774,180.

Process for Cracking Hydrocarbon Oil. Aubrey D. David, Chicago, Ill., assignor to Universal Oil Products Company, Chicago, Ill.—1,774,228.

Art of Cracking Hydrocarbon Oils. Harry L. Pelzer, Highland, Ind., assignor to Sinclair Refining Company, New York, N. Y.—1,774,291.

Coal and Organic Processes

Carbonization Process and Apparatus Therefor. Frank C. Greene, Waukegan, Ill., and Irving F. Laucks, Seattle, Wash., assignors to Old Ben Coal Corporation, Chicago, Ill.—1,771,999.

Recovery of Nitrogen and Acetone from Vinasses. Joseph Gullissen, Brussels, Belgium, Union Chimique Belge, Brussels, Belgium.—1,772,078.

Diluting Coke-Oven Gas with Flue Gas. Walter R. Knapp, Syracuse, N. Y., assignor to Semet-Solvay Company, New York, N. Y.—1,772,101.

Coking Oven and Other Furnace. Charles R. Bellamy, Caldwell, N. J., assignor of one-half to William Hutton Blauvelt, New York, N. Y.—1,772,413.

Sulphur Emulsion and Insecticide Containing the Same. Albert Hartzell and Frank Heidtman Lathrop, Geneva, N. Y., assignors to trustees of Crop Protection Institute.—1,772,511.

Gas Production. Harry F. Smith, Dayton, Ohio, assignor to the Gas Research Company, Dayton, Ohio.—1,772,641-3.

Process of Synthesizing Methane from Gases. Alfred H. White, Ann Arbor, Mich.—1,772,652.

Apparatus for Manufacturing Water Gas. William E. Steinwedell, Cleveland Heights, Ohio, assignor to the Gas Machinery Company, Cleveland, Ohio.—1,772,789.

Producer-Gas Apparatus. Ernst Schumacher, Frankfort, Germany, assignor of one-half to the Frankfurter Gasgesellschaft, Frankfort, Germany.—1,772,819.

Process of Producing a Turpentine Substitute from Pine Oil. Irvin W. Humphrey, Wharton, N. J., assignor to Hercules Powder Company, Wilmington, Del.—1,772,895.

Preparation of Acetylene and Hydrogen. Martin Banck, Bucharest, Rumania.—1,773,611.

Catalysts for Production of Methanol and Other Oxygenated Organic Compounds from Oxides of Carbon and Hydrogen. Reginald George Franklin, Billingham, Stockton-Tees, England, assignor to Imperial Chemical Industries, Ltd., London, England.—1,774,432.

Inorganic Processes

Process for the High Concentration of Nitric Acid. Fred C. Zeisberg, Wilmington, Del., assignor to E. I. duPont de Nemours & Company, Wilmington, Del.—1,772,122.

Process for Transforming Barium and Strontium Sulphates. Fritz Rothe, Aachen and Hans Prenek, assignors to Rhenania Verein Chemisches Fabriken A. G., Cologne, Germany.—1,772,269.

Process for the Manufacture of Nitric Acid. Martin Battegay, Mulhouse, Hunt Rhin, France, assignor to the Calco Chemical Company, Inc.—1,772,302.

Method of Treating Aluminum-Oxide Minerals. Thomas Austin Mitchell, Denver, Colo., assignor to Lafayette M. Hughes, Denver, Colo.—1,772,359-60.

Process for the Production of Oxygen and Nitrogen. Giovanni Cicali, Bologna, Italy.—1,772,856.

Process of Producing Phosphorus. John W. Walton, Rockdale, Tenn., assignor to Tennessee Products Corporation, Nashville, Tenn.—1,772,849.

Process for Producing Aluminum Compounds. Ture Robert Haglund, Stockholm, Sweden, assignor to International Patent Corporation.—1,772,936-7.

Process for the Separation of Gas Mixtures. Paul Schuftan, assignor to Gesellschaft Für Linde's Eismaschinen, A. G., Hollriegelskreuth, near Munich, Germany.—1,773,012.

Method of Making Gels. Ernest B. Miller, Baltimore, Md., assignor to the Silica Gel Corporation, Baltimore, Md.—1,773,273.

Apparatus for Manufacturing Acid Phosphate. Thomas J. Sturtevant, Wellesley, Mass., assignor to Sturtevant Mill Company, Boston, Mass.—1,773,287.

Process for Obtaining Elemental Sulphur and Catalysts Therefor. Raymond C. Benner, Bayside, and Alfred Paul Thompson, Jackson Heights, N. Y., assignors to General Chemical Company, New York, N. Y.—1,773,293-4.

Catalytic Converter. David F. Sirdevan, New York, N. Y., assignor to General Chemical Company, New York, N. Y.—1,773,322.

Process for Precipitating Titanium Compounds. Peder Farup, Vettakollen, Vestre Aker, Norway, assignor to Titanium Pigment Company, Inc., New York, N. Y.—1,773,727.

Process for the Preparation of Magnesium Bichromate. Georg Kränzlein and Arthur Voss, Hochst-on-the-Main, Germany, assignors to General Aniline Works, Inc., New York, N. Y.—1,774,018.

Chemical Decomposition of Crude Potash Salts. Friedrich Rüsberg, Berlin-Niederschoneweide, Germany, assignor to Kali-Chemie, Aktiengesellschaft, Berlin, Germany.—1,774,040.

Method of and Apparatus for Separating the Constituents of Gaseous Mixtures. Claude C. Van Nuys, Cranford, and Joseph L. Schlitt, Elizabeth, N. J., assignors to Air Reduction Company, Inc., New York, N. Y.—1,774,462.

Miscellaneous Processes and Equipment

Fluid Separator. Grant D. Bradshaw, Pittsburgh, Pa., assignor, by mesne assignments, to Blaw-Knox Company, Blawnox, Pa.—1,772,037.

Process for Unhairing and Preparing Hides for Tanning. Charles Joseph Michel Marie Le Petit, Paris, France, assignor to Rohm & Haas Company, Philadelphia, Pa.—1,772,258.

Process of Separating Liquids and Solids. Tandy A. Bryson, Troy, N. Y., assignor, by mesne assignments, to Tolhurst Machine Works, Inc., Troy, N. Y.—1,772,336.

Conveyer for Plastic Materials. Alpheus O. Hurxthal, Philadelphia, Pa., assignor to Proctor & Schwartz, Inc., Philadelphia, Pa.—1,772,423.

Centrifugal Machine. George W. Dunham, New Haven, Conn., assignor to Whirldry Corporation, New Haven, Conn.—1,722,602.

Heat Exchanger. Joseph Price, Stapleton, N. Y., assignor to Griscom-Russell Company, New York, N. Y.—1,773,199-200.

Counter-current Contacting Apparatus. Charles Lincoln Campbell, Boston, Mass., assignor to E. B. Badger & Sons Company, Boston, Mass.—1,773,258.

Method and Apparatus for Measuring the Concentration of Solids in Liquids. Howard J. Kerr, Bayonne,, N. J., assignor to the Babcock & Wilcox Company, Bayonne, N. J.—1,773,735.

Apparatus for Electrical Precipitation of Suspended Material from Gases. Franz Seipp, Frankfort-on-the-Main, Germany, assignor to International Precipitation Company, Los Angeles, Calif.—1,773,876.

Drying Kiln. Moritz L. Mueller, Seattle, Wash., assignor to General Dry Kiln Company.—1,774,208.

NEWS *of the* INDUSTRY

Modifications Sought for Alcohol Regulations

SEVERAL features of the new industrial alcohol regulations, now in tentative form, are objectionable to the alcohol-using trades to whom they have been submitted for criticism. Originally intended to become effective Sept. 1, it is probable that the new regulations drafted jointly by the Department of Justice and the Treasury Department will not be finally promulgated before Jan. 1.

In the tentative draft the 10-day period that now must elapse before withdrawal permits are issued has been eliminated, but the term of the permit is limited to a maximum of 90 days. The short life of the permit and restrictions on the quantities that may be withdrawn monthly and held by a permittee are regarded as imposing an unnecessary hindrance upon the legitimate trade. Basic permits would run for one year and applications would be subject to the 10-day rule.

Consumers of industrial alcohol are disturbed by other proposed requirements providing for complete suspension of a withdrawal permit following issuance of a citation for its revocation. All products in which alcohol is used in process of manufacture would be subject to the requirement that samples be submitted for approval. The ingredients used in toilet articles would be subject to scrutiny and the manufacturers of these and other products, such as thinners, solvents, and ethyl acetate, would be obliged to assume the responsibility of restricting sales to legitimate consumers.

The paper work that the proposed regulations would entail is formidable. Permit applications and formulas must be submitted in quadruplicate; specifications of chemical processes must be filed in duplicate. Records of all articles used in the manufacture of alcoholic preparations must be preserved for three years. Cards showing the signatures of all persons authorized to sign for the permittee must be filed with the local administrator.

The premises of any distiller, bonded warehouse, denaturing plant, manufacturer, or dealer would be subject to inspection at any time by any official of the Bureau of Industrial Alcohol, the Bureau of Prohibition, or any peace officer of the state. In many other respects the proposed regulations are regarded as unnecessarily burdensome by the representatives of the alcohol-using trades, and they have submitted briefs urging that several of the proposed requirements be modified before the regulations are finally issued.

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Noteworthy Papers Read At A.C.S. Meeting

HYDROGENATION will prove a new and highly flexible tool in the hands of the oil refiner, but it is not likely to displace cracking and other refining processes. This was the statement made by R. T. Haslam and R. P. Russell, of the Standard Oil Development Company, in a paper which was easily the outstanding feature of the eightieth meeting of the American Chemical Society held in Cincinnati Sept. 8 to 12.

Addressing the symposium on high-pressure reactions, which is also reported elsewhere in this issue, Haslam and Russell pointed out for the first time the five specific adaptations of hydrogenation in oil refining. They showed how sulphur would be removed from heavy high-sulphur asphaltic residues to produce 100 per cent or more of gasoline. A second use is to convert low-grade lubricating distillates into the highest grade of paraffine-base motor oils. Likewise low-grade kerosene distillate can be economically refined to burning oils and gasoline of superior quality. The fourth application is to remove sulphur and promote gum stabilization in gasoline from cracked naphthas high in sulphur. The last and one of the most interesting uses is to dehydrogenate paraffine gas oil to give anti-knock gasoline, thus emphasizing the flexibility of the whole process.

Another feature of technical interest was the symposium on industrial fermentation, held under the chairmanship of Bruce K. Brown. H. T. Herrick, who served as secretary, will report this session in a later issue of *Chem. & Met.*

Inspections of the large chemical and process plants of the Cincinnati and Dayton area were made by many of the 1,500 chemists and guests who registered at the convention. By vote of the council of the Society it was decided to hold the April, 1931, meeting in Indianapolis. The next fall meeting will go to Buffalo instead of Chautauqua, N. Y., as previously announced. In 1932 the two meetings are scheduled for New Orleans and Denver.

Explosive and Chemical Plant Projected

CONCURRENT with the filing of a deed covering 418 acres of land near New Castle, Pa., announcement is made of the entry of Burton Explosives, Inc., hitherto a sales organization, into the explosive and chemical manufacturing field. J. S. Burton, president and general manager, formerly president of the Grasselli Powder Company, is quoted as stating that an initial production of 12,000,000 lb. of high explosives in 1931 is projected.

A plant to employ over one hundred men is now under construction on the site of the former American High Explosives Company, of which Mr. Burton was general manager at the time of a merger of the Burton Powder Company with Grasselli in 1917. Manufacture of a line of heavy chemicals is proposed as a development to follow the establishment of the explosive line.

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Byproduct Fertilizer Proves a Success

THE new fertilizer which was turned out last year for the first time by the Consolidated Mining & Smelting Company at its plant at Tadanac, near Trail, B. C., as a byproduct has now been proved a decided success by actual practical tests.

Last spring, in order to give the fertilizer an extensive test, it was used in many plots throughout various parts of the Peace River country. Recently Dr. Roy E. Neidig, one of the company's chemical experts, made a trip through the district and surveyed results. All of the plots where the fertilizer was used showed heavier production.

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X-Ray Service for Welded Seams

THE St. John X-Ray Service Corporation, 505 Fifth Avenue, New York City, has installed what is said to be the first X-Ray plant of its kind at the Barberton (Ohio) works of the Babcock & Wilcox Company.

The photographic apparatus will be used primarily for routine inspection of welded seams in pressure vessels, heat exchangers, and similar equipment.

Color Analysis Features T.A.P.P.I. Meeting

THE fall meeting of the Technical Association of the Pulp and Paper Industry was held in Erie, Pa., Sept. 3, 4, and 5. Color analysis and measurement, a subject of particular interest at this time, featured the technical sessions, and the entertainment and local industries supplied one of the most interesting and enjoyable social programs of recent years.

Among the leading papers was that by Jackson Burgess, on the Razek-Mulder color analyzer for paper. This instrument is said to provide the means for making scientific color analysis, which is important in the specification of raw materials, in the control of processes in chemical manufacture, and in the establishment of standards for finished products. H. H. Sheldon described the matching of colors with the colorscope. This is based essentially upon the ability of the now well-known photoelectric cell to differentiate light both as to color and intensity and to cause a corresponding electrical response through suitable electrical circuits.

A subject of interest to every pulp and paper man was that discussed at the luncheon on Thursday by L. C. Reynolds, chairman of the new management methods committee, who outlined the committee's plan for the standardization of materials used in this industry.

Visits were made to many industrial plants, including the Hammermill Paper Company, the General Electric Company, and the Kalbfleisch Corporation.

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Toxic Effects of Methanol Under Study

WITH the danger of poisoning practically removed by the decision of methanol manufacturers to color their product when marketed as an automobile radiator anti-freeze it remains only to determine the extent of hazard when the synthetic product is absorbed through the skin or when the fumes are inhaled. At the request of the Public Health Service, the Bureau of Mines is expediting a scientific investigation of these factors at its Pittsburgh experiment station, but the usual winter demand for anti-freeze compounds will set in long before the Bureau's study is completed.

This inquiry into the toxic effects of exposure to synthetic methyl alcohol will be supplemented by a field study by the Public Health Service of the possible concentrations of fumes from automobile radiators and resulting air conditions in public and private garages and in automobiles when on the road.

Increasing use of methanol as an anti-freeze is regarded as inevitable irrespective of findings concerning its toxic effects. Some states restrict its use, but the federal government has no control over the manufacture or use of either natural wood alcohol or synthetic methanol. The American Medical Association is apprehensive that unless warning is given and precautions taken against inhaling the fumes from heated radiators, many cases of blindness and some fatalities may result. Various state and municipal health officials and medical societies are broadcasting such warnings.

The federal investigators will not predict what their findings will disclose regarding extent and degree of toxicity, but circumstantial evidence is somewhat reassuring. It appears that in natural-wood-alcohol plants workers have been exposed to the fumes for years without injury and have used the tailings to wash off tar from their hands. Years ago purified wood alcohol was used in flavoring extracts to some extent. This practice was stopped, although no toxic effects from the small quantities used were discernible.

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Corrosion Will Feature A.E.S. Fall Meeting

THE usual fall meeting of the American Electrochemical Society will be held in Detroit, Mich., on Sept. 25, 26, and 27. Headquarters for the convention will be at the Hotel Statler.

A symposium on preventing corrosion of metals in the automobile industry will feature the meeting. Dr. F. N. Speller will serve as chairman of the symposium, which is scheduled for Thursday morning, Sept. 25.

Dr. Richard Moldenke, noted metallurgist, will preside at the round-table luncheon on Friday, at which the subject of electric gray iron will be discussed. The electrodeposition division will meet Saturday, Dr. Arthur K. Graham, of the University of Pennsylvania, presiding.

Among the plants to be visited are the Ford Motor Company, Champion Porcelain Company, Ternstedt Manufacturing Company, Hoskins Manufacturing Company, General Motors Research Laboratory, and Parke Davis & Company.

CALENDAR

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, New Orleans, Dec. 8-10.

AMERICAN ELECTROCHEMICAL SOCIETY, fall meeting, Detroit, Sept. 25-27.

AMERICAN WELDING SOCIETY, fall meeting, Chicago, Sept. 22-26.

NATIONAL SAFETY COUNCIL, annual meeting, Pittsburgh, Sept. 29-Oct. 4.

AMERICAN PETROLEUM INSTITUTE, 11th annual meeting, Chicago, Nov. 10-13.

NATIONAL METAL CONGRESS, 12th annual meeting, Chicago, Sept. 22-26.

AMERICAN ENGINEERING COUNCIL, Administrative Board Meeting, Washington, Oct. 17-18.

SOCIETY OF INDEPENDENT ENGINEERS, Washington, Oct. 15-17.

Tariff Revisions In Prospect

DURING the next few weeks, tariff action under the new flexible clause will take definite form with decisions of likely importance to the chemical industry. Just how the rate change proceedings will be administered has been left to the new Tariff Commission taking office on Sept. 17. Whether the new law is successful or whether it is ineffective, as under the 1922 act, will depend entirely upon this shaping of procedure. Decisions as to which of the many pending investigations will take precedence also are important to those waiting for tariff relief. So far, there is no clear-cut indication of policy, although hope still remains that exorbitant rates on raw materials can be scaled down under a system that can operate quickly.

Only a few changes affecting chemicals were requested by Congress, and since adjournment no applications have come in except on the significant item of casein, on which a decrease has been asked. However, some branches of the industry have been busy compiling data of which some use may be made in the near future. Thus the tariff tax is by no means forgotten. The chemical division of the Tariff Commission is well under way on the several investigations listed in previous issues.

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Shell Nitrogen Plant Under Construction

CONSTRUCTION has been started by the Shell Chemical Company, a subsidiary of the Shell Oil Company, San Francisco, Calif., of a $3,000,000 nitrogen-fixation plant on the 600-acre site this company recently purchased near Pittsburg, Calif.

The site has a half mile of deep frontage on Suisun Bay and has available every power facility, including natural gas, which is not only a source of power but is probably a basic material used in further developments such as the manufacture of solvents. The electrical power equipment already purchased consists of three 600-hp., 128-r.p.m., synchronous motors; four 1,000-hp., 128-r.p.m., synchronous motors; two 700-hp., 109-r.p.m., synchronous motors; two 100-kw., 1,200-r.p.m., synchronous motor-generator sets; one 24-panel switchboard; and two 200-hp., 600-r.p.m. synchronous motors.

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Welding Society to Meet in Chicago

THE fall meeting of the American Welding Society will be held at the Congress Hotel, Chicago, Sept. 22-26. A welding exposition will open at the Stevens Hotel, on Sept. 22. A diversified program has been arranged for the technical and business sessions, all of which will be held at the Congress Hotel. Prominent on the program is a symposium on testing of welds.

MARKET CONDITIONS AND PRICE TRENDS

Deliveries of Chemicals Assume Larger Proportions

FOLLOWING the general industrial slowing up of the hot-weather period, demand for chemicals, since the turn of the month, has improved notably. This has been apparent more in an increased withdrawal of materials against running contracts than by more active buying in the spot market. Spot trading, however, has made gains, but full seasonal conditions have not yet become operative.

Price changes during the last month were of slight importance so far as chemicals were concerned. Ethyl acetate was marked down by producers, with large stocks as the ruling price factor. Heavy chemicals held a regular course. The position of oils and fats, on the other hand, was not so favorable and the average price level underwent a drastic downward revision during the period.

Opinions vary regarding the volume of chemical stocks in sellers' possession. Sales pressure noted in recent months was attributed to large accumulations. In some instances this undoubtedly was true, and perhaps the condition has not been entirely removed. In other instances curtailed production has prevented any large accumulations and with different consuming branches working on small supplies, it would not appear that the market as a whole is due to suffer from an oversupply of chemicals.

Reports from abroad stated that with the renewal of the German nitrogen syndicate, which has heretofore been confined to fertilizer products, the operations of the syndicate are now extended for the first time to nitrogen chemicals for industrial purposes. The nitrogen syndicate accounts for over 98 per cent of the entire German production of fixed nitrogen.

Chem. & Met. Weighted Index of Chemical Prices

Base = 100 for 1927

This month	**94.38**
Last month	94.15
September, 1929	100.19
September, 1928	99.16

With the exception of ethyl acetate the chemical list held a fairly steady price position in recent weeks. Alcohol was more freer from selling pressure and spirits of turpentine moved up in price and advanced the weighted index number.

Rising Volume Of Trade

In its issue of Sept. 17, *Business Week* states that the marked lull in business activity this year at the end of August and the beginning of September has been followed by a general freshening of business sentiment as signs of seasonal improvement accumulate. . . . Lengthened plant holidays and deferred check payments in the fortnight including Labor Day dropped our index to 83.5 per cent of normal, despite evidence that business recovery, beginning as usual with the basic industries and primary distribution, is proceeding normally in response to seasonal stimulus. . . . Coal and electric power production are increasing; steel output is being maintained; carloadings are rising. Expansion of commercial loans and currency circulation indicate a rising volume of wholesale and retail trade as the fall buying movement gets under way. . . . Business is beginning to feel better than it looks, but is still stymied by undue caution in making forward commitments, which is keeping working supplies of raw materials and retail stocks of finished goods below normal requirements and consumer standards. . . .

In connection with the nitrogen situation it is pointed out that about 80 per cent of world production goes into fertilizers. In this country 65 to 70 per cent of the nitrogen supply is used in agriculture. The disposal of chemical nitrogen in this country is estimated as follows:

	Tons 1914	Tons 1929
Refrigeration	6,830	15,000
Miscellaneous industrial uses	130	25,000
Chemicals and acids	22,600	63,000
Explosives*	32,500	21,000
Total industrial	62,060	124,000
Fertilizer	92,200	325,000
Grand total	154,260	449,000

*As nitrate and ammonia, but excluding nitric acid.

With demand for anti-freeze preparations looming up, considerable interest has been shown in the position of methanol as an anti-freeze product. The medical fraternity, or at least its representative publication, sees a danger to public health if methanol is permitted to be used in anti-freeze mixtures. Incidentally, domestic production of crude methanol for the first half of this year was 3,529,797 gal., as against 4,277,674 gal. for the corresponding period of 1929, or a loss of more than 17 per cent. Production of refined methanol for the same period declined from 2,787,801 gal. in 1929 to 2,216,126 gal. this year. These totals refer only to methanol produced by the wood-distillation branch of the industry.

Spirits of turpentine and rosin have fluctuated considerably in price during the month, but closed with values on an upward swing. Demand both for home and export is gaining and the low prices quoted had a stimulating effect on the buying movement.

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Helium Output Makes Large Advance

THE government's helium plant near Amarillo, Texas, designed, built, and operated by the U. S. Bureau of Mines, produced 9,801,060 cu.ft. of helium in the year ended June 30, 1930. This was the first fiscal year of operation after the plant was constructed. Although the plant operated only ten months of the fiscal year, having been closed in December, 1929, and February, 1930, for lack of orders for helium, the production was the largest ever turned out by the government in one fiscal year, being about 800,000 cu.ft. greater than the largest fiscal year's production of the government's Fort Worth helium plant, which formerly supplied helium used by the Army and Navy.

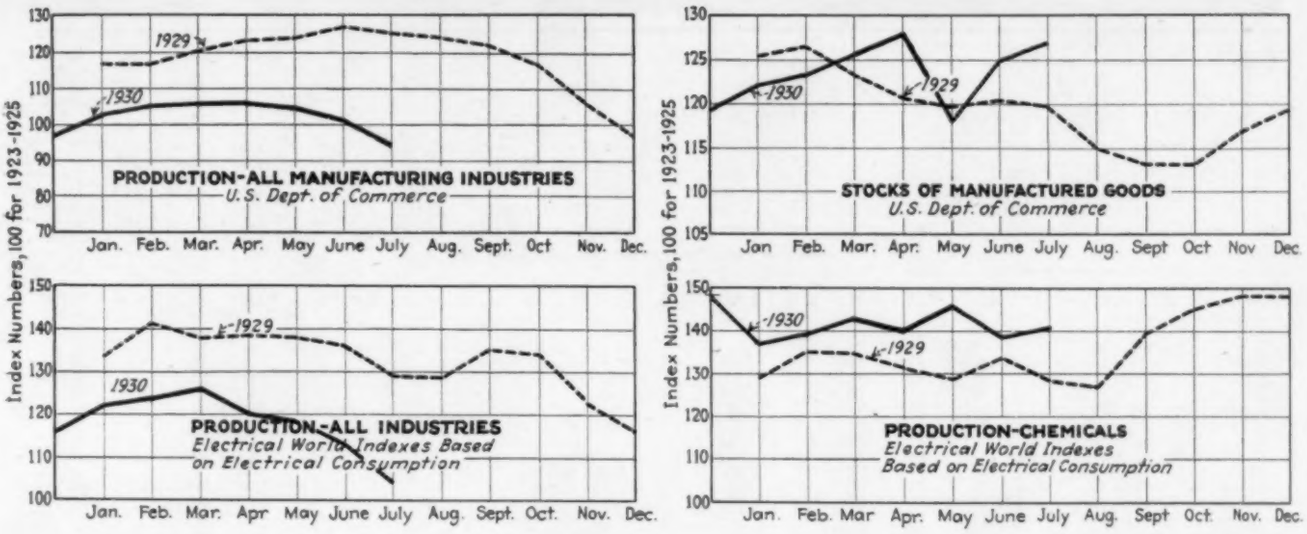
Chem. & Met. Weighted Index of Prices for Oils and Fats

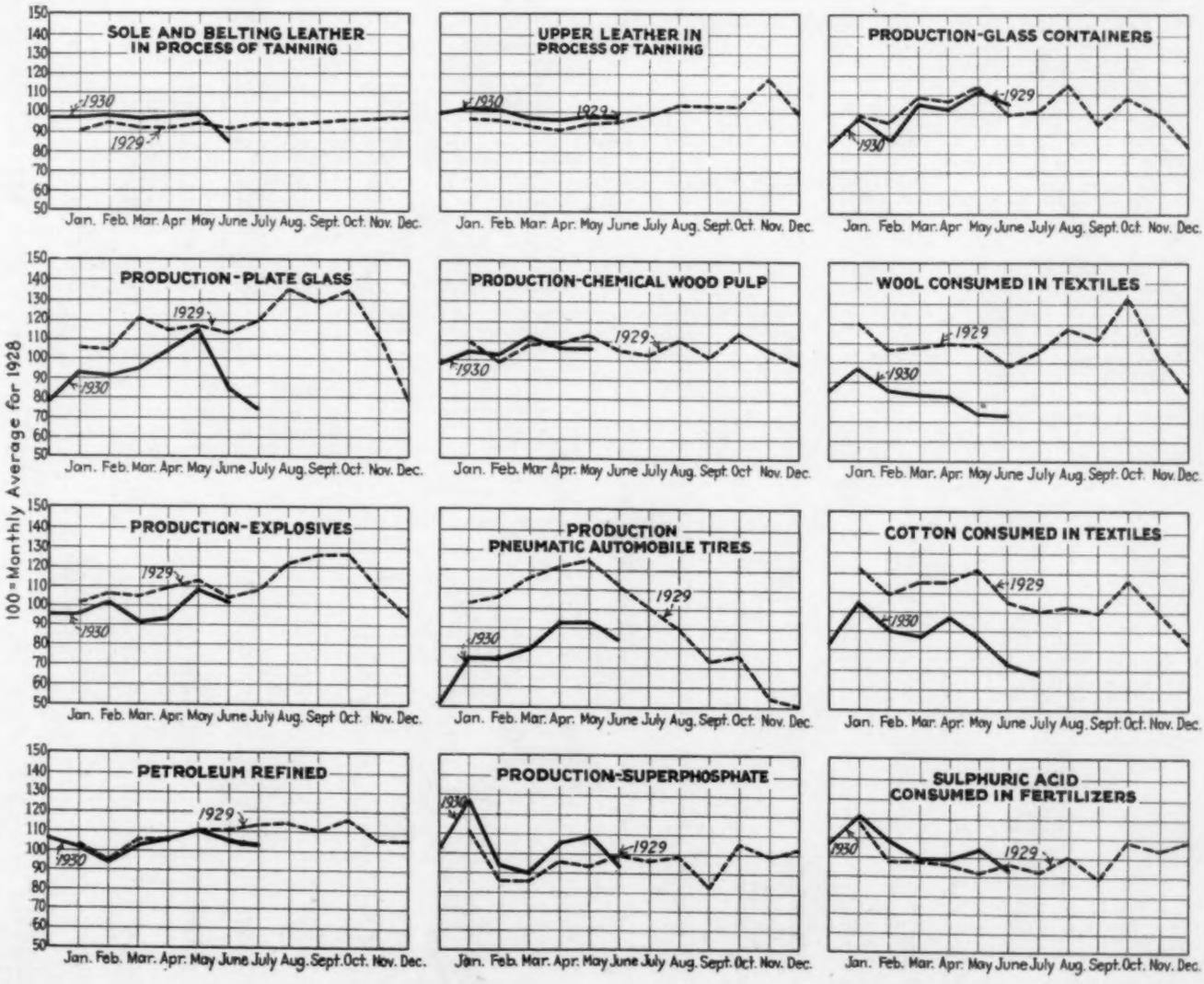
Base = 100 for 1927

This month	**77.86**
Last month	87.36
September, 1929	99.81
September, 1928	94.49

Values for oils and fats suffered an almost general decline during the month. Linseed oil was especially weak as a result of large unsold holdings. Palm oil offered an exception to the general rule and was held at higher levels than in the preceding month.

ACTIVITY IN PRODUCING AND CONSUMING INDUSTRIES


PRODUCTION-ALL MANUFACTURING INDUSTRIES
U.S. Dept. of Commerce
STOCKS OF MANUFACTURED GOODS
U.S. Dept. of Commerce
PRODUCTION-ALL INDUSTRIES
Electrical World Indexes Based on Electrical Consumption
PRODUCTION-CHEMICALS
Electrical World Indexes Based on Electrical Consumption
Index Numbers, 100 for 1923-1925
1929
1930
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.



CURRENT PRICES *in the* NEW YORK MARKET

THE following prices refer to round lots in the New York Market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to September 12.

Industrial Chemicals

	Current Price	Last Month	Last Year
Acetone, drums, lb.	$0.11 -$0.12	$0.11 -$0.12	$0.14 -$0.15
Acid, acetic, 28%, bbl., cwt.	3.11 - 3.26	3.11 - 3.26	3.88 - 4.03
Glacial 99%, tanks	10.76		
drs.	11.01 -11.26		
U. S. P. reagent, c'bys.	11.51 -11.76	12.51 -12.76	
Boric, bbl, lb.	.06½- .07	.06½- .07	.06½- .07
Citric, kegs, lb.	.46 - .47	.46 - .47	.46 - .47
Formic, bbl, lb.	.10 - .11	.10 - .11	.10½- .11
Gallic, tech., bbl., lb.	.50 - .55	.50 - .55	.50 - .55
Hydrofluoric 30% carb, lb.	.06 - .07	.06 - .07	.06 - .07
Lactic, 44%, tech., light, bbl., lb.	.11½- .12	.11½- .12	.11½- .12
22%, tech., light, bbl., lb.	.05½- .06	.05½- .06	.05½- .06
Muriatic, 18°, tanks, cwt.	1.00 - 1.10½	1.00 - 1.10	1.00 - 1.10
Nitric, 36°, carboys, lb.	.05 - .05½	.05 - .05½	.05 - .05½
Oleum, tanks, wks., ton	18.50 -20.00	18.50 -	18.00- 20.00
Oxalic, crystals, bbl., lb.	.11 - .11½	.11 - .11½	.11 - .11½
Phosphoric, tech., c'bys., lb.	.08½- .09	.08½- .09	.08½- .09
Sulphuric, 60°, tanks, ton	11.00 -11.50	11.00 -11.50	11.00 -11.50
Tannic, tech., bbl., lb.	.35 - .40	.35 - .40	.35 - .40
Tartaric, powd., bbl., lb.	.34 - .36	.34½- .36	.38 - .39
Tungstic, bbl., lb.	1.40 - 1.50	1.40 - 1.50	1.00 - 1.20
Alcohol, ethyl, 190 p'f., bbl., gal.	2.63 -	2.63 - 2.71	2.68½- 2.71
Alcohol, Butyl, tanks, lb.	.16½- .17	.16½- .17	.16½- .17
Alcohol, Amyl			
From Pentane, tanks, lb.	.236-	.236-	
Denatured, 188 proof			
No. 1 special dr., gal.	.40 -	.39 -	.50 -
No. 5, 188 proof, dr., gal.	.40 -	.39 -	.50 -
Alum, ammonia, lump, bbl., lb.	.03½- .04	.03½- .04	.03½- .04
Chrome, bbl., lb.	.05 - .05½	.05½- .05½	.05½- .06
Potash, lump, bbl., lb.	.03½- .04	.03 - .03½	.02½- .03½
Aluminum sulphate, com., bags, cwt.	1.40 - 1.45	1.40 - 1.45	1.40 - 1.45
Iron free, bg., cwt.	1.90 - 2.00	1.90 - 2.00	2.00 - 2.10
Aqua ammonia, 26°, drums., lb.	.03 - .04	.03 - .04	.03 - .04
tanks, lb.	.02½- .02¾		
Ammonia, anhydrous, cyl., lb.	.15½-	.15½-	.14 -
tanks, lb.	.05½-	.05½-	
Ammonium carbonate, powd. tech., casks, lb.	.10½- .11	.10½- .11	.12 - .13
Sulphate, wks., cwt.	1.70 -	1.85 -	2.20 -
Amylacetate tech., tanks, lb., gal.	.222-	2.22 -	
Antimony Oxide, bbl., lb.	.08½- .10	.08½- .10	.09 - .10
Arsenic, white, powd., bbl., lb.	.04 - .04½	.04 - .04½	.04 - .04½
Red, powd., kegs., lb.	.09 - .10	.09 - .10	.09 - .10
Barium carbonate, bbl., ton	58 00 -60.00	58 00 -60.00	57.50 -60 00
Chloride, bbl., ton	63.00 -65.00	63.00 -65.00	64.00 -70.00
Nitrate, cask, lb.	.07 - .07½	.07 - .07½	.08 - .08½
Blanc fixe, dry, bbl., lb.	.03½- .04	.03½- .04	.04 - .04½
Bleaching powder, f.o.b., wks., drums, cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Borax, bbl., lb.	.033- .033	.033- .033	.02½- .03
Bromine, cs., lb.	.45 - .47	.45 - .47	.45 - .47
Calcium acetate, bags	3.00 -	3.00 -	4.50 -
Arsenate, dr., lb	.07 - .08	.07 - .10	.06½- .07
Carbide drums, lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., wks., ton.	20 00 -	20 00 -	20.00 -
flake, dr., wks., ton.	22.75 -	22.75 -	22.75 -
Phosphate, bbl., lb.	.08 - .08½	.08 - .08½	.07 - .07½
Carbon bisulphide, drums, lb.	.05½- .06	.05½- .06	.05 - .06
Tetrachloride drums, lb.	.06½- .07	.06½- .07	.06½- .07
Chlorine, liquid, tanks, wks., lb.	.024-	.024-	.03 -
Cylinders	.04 - .06	.04 - .06	.05 - .08
Cobalt oxide, cans, lb.	2.10 - 2.20	2.10 - 2.20	2.10 - 2.25
Copperas, bgs., f.o.b. wks., ton.	13.00 -14.00	13.00 -14.00	16.00 -17.00
Copper carbonate, bbl., lb.	.09 - .18	.09 - .18	.19 - .21
Cyanide, tech., bbl., lb.	.45 - .46	.45 - .46	.49 - .50
Sulphate, bbl., cwt.	4.25 - 4.50	4.25 - 4.50	6.00 - 6.10
Cream of tartar, bbl., lb.	.26 - .27	.26 - .27	.27½- .28
Diethylene glycol, dr., lb.	.11 - .13	.11 - .13	.10 - .15
Epsom salt, dom., tech., bbl., cwt.	1.75 - 2 15	1.75 - 2.00	1.75 - 2.00
Imp., tech., bags, cwt.	1.15 - 1.25	1.15 - 1.25	1.15 - 1.25
Ethyl acetate, drums, lb.	.096-	.103-	.125-
Formaldehyde, 40%, bbl., lb.	.07½- .08	.07½- .08	.08½- .09
Furfural, dr., contract, lb.	.10 - .12	.10 - .12	.15 - .17
Fusel oil, crude, drums, gal.	1 30 - 1.40	1.30 - 1.40	1.30 - 1.40
Refined, dr., gal.	1.90 - 2.00	1.90 - 2.00	2.50 - 3.00
Galubers salt, bags, cwt.	1.10 - 1.20	1.10 - 1.20	1.00 - 1.10
Glycerine, c.p., drums, extra., lb.	.13 - 13½	.13 - .13½	.14 - .15
Lead:			
White, basic carbonate, dry casks, lb.	.07½-	.07½-	.09 -
White, basic sulphate, sck., lb.	.07½-	.07½-	.08½-
Red, dry, sck., lb.	.09 -	.09 -	.10 -
Lead acetate, white crys., bbl., lb.	.12 - .13	.13 - .14	.13 - .13½
Lead arsenate, powd., bbl., lb.	.13 - .14	.13 - .14	.12 - .13
Lime, chem., bulk, ton	8.50 -	8.50 -	8.50 -
Litharge, pwd., csk, lb.	.08 -	.07½-	.09½-
Lithopone, bags, lb.	.05½- .06	.05½- .06	.05½- .06½
Magnesium carb., tech., bags, lb.	.06 - .06½	.06 - .06½	.06½- .07
Methanol, 95%, tanks, gal.	38 -	.38 -	55 -
97%, tanks, gal.	39 -	.39 -	55 -
Synthetic, tanks, gal.	.40½- .45	.40½-	
anti-freeze, 76½%, tanks, gal.	.31	.31 -	
Nickel salt, double, bbl., lb.	.13 - .13½	.13 - .13½	.13 - .13½
Single, bbl., lb.	.13 - .13½	.13 - .13½	.13 - .13½
Orange mineral, csk., lb	.11 -	.11 -	.12½-
Phosphorus, red, cases, lb.	.42 - .44	.42 - .44	.55 - .57
Yellow, cases, lb.	.31 - .32	.31 - .32	.32 - .33
Potassium bichromate, casks, lb.	.09 - .09½	.09 - .09½	.09 - .09½
Carbonate, 80-85%, calc., csk., lb	.05½- .06	.05½- .06	.05½- .06
Chlorate, powd., lb.	.08½- .09	.08½- .09	.07½- .08½
Cyanide, cs., lb.	.57½- .58	.52 - .55	.51 - .53
First sorts, csk., lb.	.08½- .09	.08½- .09	.08½- .09
Hydroxide (c'stic potash) dr., lb	.06½- .06¾	.06½- .06¾	.07½- .07¾
Muriate, 80% bgs., ton	37.15 -	37.15 -	36.75 -
Nitrate, bbl., lb.	.06 - .06½	.06 - .06½	.06 - .07½
Permanganate, drums, lb.	.16 - .16½	.16 - .16½	.16 - .16½
Prussiate, yellow, casks, lb	.18½- .19½	.18½- .19	.19 - .19½
Sal ammoniac, white, casks, lb	.046- .05	.046- .05	.047- .05
Salsoda, bbl., cwt.	.90 - .95	.90 - .95	.90 - .95
Salt cake, bulk, ton	18.00 -20.00	18.00 -20.00	16.00 -18.00
Soda ash, light, 58%, bags, contract, cwt.	1.32 -	1.32 -	1.32 -
Dense, bags, cwt.	1.35 -	1.35 -	1.35 -
Soda, caustic, 76%, solid, drums, contract, cwt.	2.90 - 3.00	2.90 - 3.00	2.90 - 3.00
Acetate, works, bbl., lb.	.04 - .05	.04 - .05	.05 - .05½
Bicarbonate, bbl., cwt.	2.00 - 2.25	2.00 - 2.25	2.00 - 2.25
Bichromate, casks, lb.	.07 - .07½	.07 - .07½	.07 - .07½
Bisulphate, bulk, ton	14.00 -16.00	14.00 -16.00	12.00 -15.00
Bisulphite, bbl., lb.	.03½- .04	.03½- .04	.03½- .04
Chlorate, kegs, lb	.05½- .07½	.07½- .08	.06½- .06½
Chloride, tech., ton	12.00 -14.75	12.00- 14.75	12.00 -14.00
Cyanide, cases, dom., lb.	.17 - .18	.18 - .22	.18 - .22
Fluoride, bbl., lb.	.08½- .09	.08½- .09½	.08½- .09
Hyposulphite, bbl., lb.	2.40 - 2.50	2.40 - 2.50	2.50 - 3.00
Nitrate, bags, cwt.	1.99 -	2 07 -	2.10 -
Nitrite, casks, lb.	.07½- .08	.07½- .08	.07½- .08
Phosphate, dibasic, bbl., lb.	.03 - .03½	.03 - .03½	.03½- .03¾
Prussiate, yel. drums, lb	.11½- .12	.11½- .12	.11½- .12
Silicate (30°, drums), cwt.	.60 - .70	.60 - .70	.75 - 1.15
Sulphide, fused, 60-62%, dr., lb.	.02¾- .03½	.02¾- .03	.03½- .04
Sulphite, cyrs., bbl., lb.	.03 - .03½	.03 - .03½	.02½- .03
Sulphur, crude at mine, bulk, ton	18 00 -	18.00 -	18.00 -
Chloride, dr., lb.	.05 - .06	.04 - .05	.04 - .05
Dioxide, cyl., lb.	.06½- .07	.07 - .08	.09 - .10
Flour, bag, cwt.	1.55 - 3.00	1.55 - 3.00	1.55 - 3.00
Tin bichloride, bbl., lb.	nom. -	nom. -	.14½-
Oxide, bbl., lb.	.36 -	.36 -	.53 -
Crystals, bbl., lb.	.27½-	.27½-	.35½-
Zinc chloride, gran., bbl., lb.	.06½- .06¾	.06½- .06¾	.06½- .06¾
Carbonate, bbl., lb.	.10½- .11	.10½- .11	.10 - .11
Cyanide, dr., lb.	.41 - .42	.40 - .41	.40 - .41
Dust, bbl., lb.	.07½- .08	.08 - .08½	.09 - .10
Zinc oxide, lead free, bag, lb.	.06½-	.06½-	.06½-
5% lead sulphate, bags, lb.	.06½-	.06½-	.06½-
Sulphate, bbl., cwt.	3 00 - 3.25	2.75 - 3.00	2.75 - 3.00

Oils and Fats

	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb.	$0.11½-$0.12½	$0.11½-$0.12½	$0.13½-$0.14
Chinawood oil, bbl., lb.	.09½-	.09½-	.14½-
Coconut oil, Ceylon, tanks, N.Y., lb.	.06½-	.06½-	.06½-
Corn oil crude, tanks, (f.o.b. mill), lb.	.07½-	.07½-	.07½-
Cottonseed oil, crude (f.o.b. mill), tanks, lb.	.06½-	.07 -	.07½-
Linseed oil, raw, car lots, bbl., lb.	.106-	.138-	.128-
Palm, Lagos, casks, lb.	.06½-	.06 -	.07½-
Niger, casks, lb.	.06½-	.05½-	.07½-
Palm Kernel, bbl., lb.	.06½-	.07 -	.08½-
Peanut oil, crude, tanks (mill), lb.	.07½-	.07½-	.08½-
Rapeseed oil, refined, bbl., gal.	.58 - .60	.58 - .60	.82 - .84
Soya bean, tank (f.o.b. Coast), lb.	.08½-	.08½-	.09½-
Sulphur (olive foots), bbl., lb.	.07½-	.07½-	.09 -
Cod, Newfoundland, bbl., gal.	.53 - .55	.55 - .57	.65 - .67
Menhaden, light pressed, bbl., gal.	.47 - .49	.47 - .49	.70 - .72
Crude, tanks (f.o.b. factory), gal.	.28 -	.27½-	.43 -
Whale, crude, tanks, gal.	.78 -	.78 -	- .80
Grease, yellow, loose, lb.	.04½-	.04½-	.06½-
Oleo stearine, lb.	.08½-	.08½-	.09½-
Red oil, distilled, d.p. bbl., lb.	.09½-	.09 -	.09½- .09¾
Tallow, extra, loose, lb.	.05 -	.05½-	.08½-

Coal Tar Products

	Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl., lb.	$0.60 -$0.65	$0.60 -$0.65	$0.60 -$0.62
Refined, bbl., lb.	.80 - .85	.80 - .85	.85 - .90
Alpha-naphthylamine, bbl., lb.	.32 - .34	.32 - .34	.35 - .36
Aniline oil, drums, extra, lb.	.15 - .15½	.15 - .15½	.15 - .16
Aniline salts, bbl., lb.	.24 - .25	.24 - .25	.24 - .25
Anthracene, 80%, drums, lb.	.60 - .65	.60 - .65	.60 - .65

Coal-Tar Products (Continued)

	Current Price	Last Month	Last Year
Benzaldehyde, U.S.P., dr., lb.	1.15 - 1.25	1.15 - 1.35	1.15 - 1.25
Benzidine base, bbl., lb.	.65 - .67	.65 - .67	.70 - .72
Benzoic acid, U.S.P., kgs, lb.	.57 - .60	.57 - .60	.58 - .60
Benzyl chloride, tech., dr., lb.	.25 - .26	.25 - .26	.25 - .26
Benzol, 90%, tanks, works, gal.	.21 - .23	.21 - .23	.22 - .23
Beta-naphthol, tech., drums, lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr., lb.	.14 - .17	.14 - .17	.18 - .20
Cresylic acid, 97%, dr., wks., gal.	.60 - .70	.60 - .70	.73 - .75
Diethylaniline, dr., lb.	.55 - .58	.55 - .58	.58 - .60
Dinitrophenol, bbl., lb.	.30 - .32	.30 - .31	.31 - .35
Dinitrotoleun, bbl., lb.	.16 - .17	.16 - .17	.17 - .18
Dip oil, 25% dr., gal.	.26 - .28	.26 - .28	.28 - .30
Diphenylamine, bbl., lb.	.39 - .40	.39 - .40	.45 - .47
H-acid, bbl., lb.	.68 - .70	.68 - .70	.63 - .65
Naphthalene, flake, bbl., lb.	.04½ - .05	.04½ - .05	.05 - .06
Nitrobenzene, dr., lb.	.08½ - .09	.08½ - .09	.08½ - .10
Para-nitraniline, bbl., lb.	.51 - .55	.51 - .55	.52 - .53
Para-nitrotoluine, bbl., lb.	.29 - .30	.29 - .31	.28 - .32
Phenol, U.S.P., drums, lb.	.14½ - .15	.14½ - .15	.15 - .17
Picric acid, bbl., lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr., lb.	1.50 - 1.80	1.50 - 1.80	1.35 - 1.50
R-salt, bbl., lb.	.44 - .45	.44 - .45	.47 - .49
Resorcinal, tech., kegs, lb.	1.15 - 1.25	1.15 - 1.25	1.30 - 1.40
Salicylic acid, tech., bbl., lb.	.33 - .35	.33 - .35	.30 - .32
Solvent naphtha, w.w., tanks, gal	.28 - .30	.28 -	.35 -
Tolidine, bbl., lb.	.91 - .93	.91 - .93	.95 - .96
Toluene, tanks, works, gal.	.35 -	.35 -	.35 -
Xylene, com., tanks, gal.	.25 - .28	.25 - .28	.36 - .40

Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton	$23.00-$25.00	$23.00-$25.00	$23.00-$25.00
Casein, tech., bbl., lb.	.13½ - .16	.13½ - .15	.15½ - .16
China clay, dom., f.o.b. mine, ton	8.00 -20.00	8.00 -20.00	10.00 -20.00
Dry colors:			
Carbon gas, black (wks.), lb.	.05 - .22	.05 - .22	.06½ - .07
Prussian blue, bbl., lb.	.35 - .36	.35 - .36	.31 - .32
Ultramine blue, bbl., lb.	.06 - .32	.06 - .32	.03 - .35
Chrome green, bbl., lb.	.27 - .28	.27 - .28	.27 - .30
Carmine red, tins, lb.	6.00 - 6.50	6.00 - 6.50	5.25 - 5.50
Para toner, lb.	.77 - .80	.77 - .80	.70 - .80
Vermilion, English, bbl., lb.	1.90 - 2.00	1.90 - 2.00	1.80 - 1.85
Chrome yellow, C. P., bbl., lb.	.17 - .17½	.17 - .17½	.15½ - .16
Feldspar, No. 1 (f.o.b. N.C.), ton	6.50 - 7.50	6.50 - 7.50	5.75 - 7.00
Graphite, Ceylon, lump, bbl., lb.	.04 - .05	.04 - .05	.08 - .09
Cum copal Congo, bags, lb.	.07 - .09	.07 - .08	.07½ - .08
Manila, bags, lb.	.16 - .17	.16 - .17	.15 - .18
Damar, Batavia, cases, lb.	.16 - .16½	.16 - .19	.22 - .23
Kauri No. 1 cases, lb.	.48 - .50	.48 - .53	.48 - .53
Kieselguhr (f.o.b. N. Y.), lb.	50.00 -55.00	50.00 -55.00	50.00 -55.00
Magnesite, calc, ton	40.00 -	40.00 -	40.00 -
Pumice stone, lump, bbl., lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks, lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H., bbl.	6.15 -	5.25 -	8.50 -
Turpentine, gal.	.43½ -	.40 -	.51 -
Shellac, orange, fine, bags, lb.	.50 - .52	.50 - .52	.61 - .62
Bleached, bonedry, bags, lb.	.36 - .37	.36 - .37	.56 - .60
T. N. bags, lb.	.27 - .28	.27 - .28	.46 - .47
Soapstone (f.o.b. Vt.), bags, ton	10.00 -12.00	10.00 -12.00	10.00 -12.00
Talc, 200 mesh (f.o.b. Vt.), ton.	9.50 -	9.50 -	10.50 -
300 mesh (f.o.b. Ga.), ton	7.50 -10.00	7.50 -10.00	7.50 -11.00
225 mesh (f.o.b. N. Y.), ton.	13.75 -	13.75 -	13.75 -

	Current Price	Last Month	Last Year
Wax, Bayberry, bbl., lb.	$0.22 -$0.24	$0.22 -$0.24	$0.28 -$0.30
Beeswax, ref., light, lb.	.35 - .36	.35 - .36	.41 - .42
Candelilla, bags, lb.	.18 - .20	.18 - .20	.23 - .24
Carnauba, No. 1, bags, lb.	.28 - .29	.28 - .29	.50 - .51
Paraffine, crude 105-110 m.p., lb.	.04 - 04½	.04 - .05	04½ - .05

Ferro-Alloys

	Current Price	Last Month	Last Year
Ferrotitanium, 15-18%, ton	$200 00-	$200.00-	$200.00-
Ferromanganese, 78-82%, ton	94 00 99 00	94.00-99.00	105.00-
Spiegeleisen, 19-21%, ton	34.00-	34.00-	32.00-
Ferrosilicon, 14-17%, ton	39.00-	39.00-	45.00-
Ferrotungsten, 70-80%, lb.	1.20 -	1.20-	1.35-
Ferro-uranium, 35-50%, lb.	4.50-	4.50-	4.50-
Ferrovanadium, 30-40%, lb.	3.15- 3.50	3.15- 3.75	3.15- 3.75

Non-Ferrous Metals

	Current Price	Last Month	Last Year
Copper, electrolytic, lb.	$0.1075	$0.10775-	$0.18½ -
Aluminum, 96-99%, lb.	.233	.233-	.24 - .25
Antimony, Chin. and Jap., lb.	.08 - .08½	.08 - .08½	.09½ -
Nickel, 99%, lb.	.35 -	.35 -	.35 -
Monel metal, blocks, lb.	.28 -	.28 -	.28 -
Tin, 5-ton lots, Straits, lb.	.301-	.301-	.45¼ -
Lead, New York, spot, lb.	.055-	.055	.07 -
Zinc, New York, spot, lb.	.046-	.048	.07 -
Silver, commercial, oz.	.36 -	.34½ -	.52½ -
Cadmium, lb.	70 - .75	.70 - .75	.85 - .95
Bismuth, ton lots, lb.	1.00 -	1.00 -	1.70 -
Cobalt, lb.	2.50 -	2.50 - 2.50	2.50 -
Magnesium, ingots, 99%, lb.	85 - 1.10	.85 - 1.10	.85 - 1.10
Platinum, ref., oz.	43 00 45.00	43.00- 45.00	70.00 70.00
Palladium ref., oz.	23.00 24.00	23.00- 24.00	42.00-46.00
Mercury, flask, 75 lb.	117.00-	116.00-	123.00-
Tungsten powder, lb.	1 70- 1 75	1.70- 1.75	1.10- 1.15

Ores and Semi-finished Products

	Current Price	Last Month	Last Year
Bauxite, crushed, wks., ton	$7.50- $8.00	$7.50- $8.50	$5.50- $8.75
Chrome ore, c.f. post, ton	21.50- 25 00	21.50- 25.00	22.00- 23.00
Coke, fdry., f.o.b. ovens, ton	2 75- 2 85	2.75- 3.85	2.85- 3.00
Fluorspar, gravel, f.o.b. Ill., ton	18 00- 20.00	18.00- 20.00	17.00- 18.00
Manganese ore, 50% Mn., c.i.f. Atlantic Ports, unit	.31 - .36	.31 - .36	.36 - .38
Molybdenite, 85% MoS_2 per lb. MoS_2, N. Y., lb.	.48 - .50	.48 - .50	.48- .50
Monazite, 6% of ThO_2, ton	60.00-	60.00-	130.00-
Pyrites, Span. fines, c.i.f., unit	.13 -	.13 -	.13 -
Rutile, 94-96% TiO_2, lb.	.10 - .11	.10 - .11	.11 - .13
Tungsten, scheelite, 60% WO_3 and over, unit	15 25- 16.50	15 25 -16.50	11.25 -11.50
Zircon, 99%, lb.	.03 -	.03 -	.03 -

CURRENT INDUSTRIAL DEVELOPMENTS

New Construction and Machinery Requirements

Abrasive Factory — Norton Co. of Canada Ltd., 3 Beach Rd., Hamilton, Ont., plans the installation of equipment for the manufacture of abrasives for proposed 3 story, 50 x 50 ft. addition to plant.

Aluminum Parts Factory — C. W. Brandt, Francis Palms Bldg., Detroit, Mich., Archt., is receiving bids for the construction of a 1 story, 40 x 300 ft. aluminum parts factory on Joseph Campau Ave. for Bohn Aluminum & Brass Co., 2512 East Grand Blvd., Detroit. Estimated cost $45,000.

Brass Plant Addition — Anaconda American Brass Ltd., New Toronto, Ont., awarded masonry contract for 70 x 450 and 98 x 200 ft. additions to brass plant. Estimated cost $200,000.

Chemical Bottling Plant—Merrimac Chemical Co., Chemical Lane, Everett, Mass., awarded contract for a 2 story, 50 x 172 ft. chemical bottling plant to A. C. Peters Inc., 46 Cornhill, Boston. Estimated cost $60,000.

Chemical Plant — Calco Chemical Co., Bound Brook Rd., Bound Brook, N. J., awarded contract for a 4 story, 40 x 105 ft. plant to Wigton-Abbott Co., 557 West 23rd St., New York, N. Y. Estimated cost $40,000.

Chemical Plant—Upjohn Co., Kalamazoo, Mich., is receiving bids for the construction of a 1 story, 50 x 170 ft. chemical plant at Front and Pontotoc Sts., Memphis, Tenn. Estimated cost $30,000. Hanker & Cairns, Court Sq. Bldg., Memphis, Tenn., are architects.

Creosoting Plant Additions—Vancouver Creosoting Co. Ltd., North Vancouver, B. C., awarded contracts for additions to creosoting plant, including wharf, tanks, treating cylinder and machinery. Estimated cost $150,000.

Coke Plant—New England Fuel & Transportation Co., 201 Rover St., Everett, Mass., awarded contract for a coke plant and factory building to Koppers Construction Co., c/o owner. Estimated total cost $50,000.

Color and Gum Works—Anchor Color & Gum Works, Dighton, Mass., will soon award contract for a power plant. Estimated cost to exceed $40,000. E. I. Marvell, 290 Bedford St., Fall River, is architect.

Drug and Perfume Factory—Connecticut Drug & Perfume Co., 108 State St., New Haven, Conn., awarded contract for a 4 story, 50 x 200 ft. factory on Orange Ave., West Haven to Fusco & Amatrude, 59 Amity Rd., New Haven. Estimated cost $160,000.

Explosives Plant — Burton Explosives Inc., New Castle, Pa., plans the construction of a 2 story, 100 x 100 ft. plant at Covert Station. Estimated cost $25,000. Private plans. Some machinery will be required.

Fertilizer Plant—Davison Gulfport Fertilizer Co., Gulfport, Miss., awarded contract for a 50 x 100 ft. addition to plant to A. Ziegenfelder, Hewes Building, Gulfport.

Gas Plant—Central Indiana Co., E. A. Angley, Gen. Mgr., Muncie, Ind., will build a gas plant. Estimated cost $1,000,000. Work will be done by owners forces. Also plans to expend $1,000,000 for additional gas production machinery and equipment.

Gas Plant—Union Carbide & Chemical Co., subsidiary of Union Carbide & Carbon Corp., 30 East 42nd St., New York, N. Y., plans the con-

struction of a pyrofax gas plant on Ramsey Ave., Hillside, N. J. Estimated cost $40,000. Architect not selected.

Gas and Coking Plant—Fort William Gas Co., Fort William, subsidiary of Canadian Terminal Systems, Ltd., 1106 Canadian Pacific Bldg., Toronto, Ont., plans the construction of a plant including six main buildings and a low temperature carbonization process plant at Fort William. Estimated cost $400,000.

Glass Plant—Du Pont Viscoloid Co., 511 Lancaster St., Leominster, Mass., awarded contract for a 3 story, 70 x 125 ft. glass plant unit, Building No. 100, to Wiley & Foss, Central St., Fitchburg. Estimated cost to exceed $40,000.

Chemistry Building—Miami University, A. T. Connar, Dir. of Public Works, Oxford, O., awarded contract for a 2 story, 120 x 167 ft. chemistry building at campus to J. Wespiper, Oxford. $74,678.

Laboratory — Huntington Laboratories, Huntington, Ind., awarded contract for the construction of a laboratory to N. Scheer & Son, 508 North La Fauntaine St., Huntington. Estimated cost $45,000.

Laboratory, Etc. — Independent Oil Refining Co., S. Erickson, Oil City, Pa., awarded contract for a 1 and 2 story laboratory and shop building at Seneca St. Ext. to L. O. Bouquin Co., 13 East First St., Oil City. Estimated cost $40,000.

Laboratory—Trubek Laboratories, East Rutherford, N. J., awarded contract for a 1 story, 45 x 160 ft. laboratory to John J. O'Leary Co., 125 Prospect St., Passaic. Estimated cost $40,000.

Laboratories—Bd. of Education, N. W. Ladegard, Secy., Sidney, Neb., will soon award contract for a 2 and 3 story, 171 x 194 ft. high school including laboratories, etc. F. W. Clarke, 706 World-Herald Bldg., Omaha, is architect.

Laboratories — California School of Technology, Pasadena, Calif., is having plans prepared for a 2 story laboratory. Estimated cost $800,000. Goodhue & Associates, New York, N. Y., are architects.

Laboratory (Drug)—Brunswig Drug Co., 501 North Main St., Los Angeles, Calif., will receive bids about Sept. 25 for a 5 story, 100 x 155 ft. laboratory on Second St. A. C. Martin, Higgins Bldg., Los Angeles, is architect.

Laboratory (Medical) — Long Island College Hospital, Pacific and Henry Sts., Brooklyn, N. Y., plans the construction of a medical laboratory. Estimated cost to exceed $100,000. W. Higginson, 101 Park Ave., New York, is architect.

Laboratory (Pathological) — Dept. of Hospitals, Municipal Bldg., New York, N. Y., awarded contract for the construction of a pathological laboratory at Sea View Hospital, Richmond, S. I., to Henney Contracting Co., 2 Lafayette St., New York. Estimated cost $20,000.

Laboratories (Chemical)—Bd. of Education, H. Woolf, Clk., Alliance, O., will soon award contract for a 2 story, 120 x 137 ft. high school including chemical laboratories. Estimated cost $185,000. Fox, Duthie Foose, Union Trust Bldg., Cleveland, are architects.

Laboratories (Chemical)—Bd. of Regents of University of California, Berkeley, Calif., will soon award contract for a group of buildings, including laboratory, etc. $685,000. G. W. Kelham, 315 Montgomery St., San Francisco, is architect, H. J. Brunnier, Sharon Bldg., San Francisco, is engineer; also awarded contracts for chemical and insectary buildings at Riverside.

Laboratories (Physics and Chemical) — Bd. of Education, I. J. Walker, Secy., East Union Ave., Somerset, Pa., will receive bids until Sept. 22 for a 3 story, 123 x 148 ft. high school including physics and chemical laboratories, etc. Estimated cost $150,000. E. H. Walker & Mong, 226 East Church St., Somerset, are architects.

Ore Washing Plant—Cleveland Cliffs Mining Co., Coleraine, Minn., awarded contract for foundation for a 100 x 200 ft. ore washing plant to E. W. Coons Co., Hibbing. Estimated cost $260,000.

Paint Factory—Dominion Paint Works Ltd, Ottawa St. and Argyle Rd., Walkerville, Ont., awarded contract for a 5 story 60 x 100 ft. addition to factory to W. H. Yates, c/o owner. Estimated cost $90,000. New equipment will be installed.

Paint Factory—Richmond Paint Products Co., 1401 Barrett Ave., Richmond, Calif., is having plans prepared for a 1 story factory. Estimated cost $40,000. Private plans.

Paint and Varnish Factory—Paragon Paint & Varnish Co., 47 10th St., Long Island City, N. Y., will receive bids about Oct. 15 for the construction of a factory at 10th St. and Vernon Ave. Estimated cost to exceed $40,000. L. A. Abramson, 46 West 46th St., New York, N. Y., is architect.

Paint Manufacturing Plant—Benjamin Moore & Co., Carteret, N. J., awarded contract for a 2 story addition to paint manufacturing plant to John Caelle, 17 Atlantic Ave., Carteret. Estimated cost $40,000.

Filter Plant — Lowe Paper Co., River Rd., Ridgefield, N. J., is having plans prepared for a 1 story, 45 x 115 ft. filter plant. Estimated cost $40,000. F. L. Smith, 21 East 40th St., New York, N. Y., is architect.

Paper Mill—International Paper Co., 220 East 42nd St., New York, N. Y., is having preliminary surveys made for the construction of a paper mill at Pueblo, Salida or Alamosa, Colo. Estimated cost between $2,500,000 and $5,000,000.

Paper Mill—Pacific Coast Paper Mills, Bellingham, Wash., plans extensions to paper mill to increase capacity to 60 carloads daily. Estimated cost $500,000.

Paper Plant—Beach & Arthur Inc., 221 West South St., Indianapolis, Ind., awarded contract for a 1 story, 200 x 300 ft. paper plant at 2900 Columbia Ave., to H. Fittou, 958 North Pennsylvania St., Indianapolis. Estimated cost $75,000.

Pottery Plant—A. H. Hews & Co. Inc., 205 Richdale Ave., Cambridge, Mass., awarded contract for the construction of a pottery plant to Stone & Webster Inc., 49 Federal St., Boston. $50,000.

Powder Blending Buildings — Construction Quartermaster, Picatinny Arsenal, Dover, N. J., will receive bids until Sept. 29, for cannon powder blending buildings. Estimated cost $150,000. Private plans.

Oil Compounding and Barreling Plant — Quaker Petroleum Co., 14th and Nicholas Sts., Omaha, Neb., awarded contract for the construction of a 56 x 210 and 60 x 96 ft. oil compounding and barreling plant at 20th and Hickory Sts., to Parsons Construction Co., Grain Exchange Bldg., Omaha. Estimated cost $50,000.

Refinery — Gulf Refining Co., Frick Bldg. Annex, Pittsburgh, Pa., awarded contract for a refinery including 50 x 80 ft. machine shop, etc. at Neville Island to W. F. Trimble & Sons Co., 1719 Pennsylvania Ave., Pittsburgh. Plans now under way for hot oil building, gas plant, and pump house, compressor building, gas plant accumulator and pump house. Owner also plans addition and alterations to pump house, three steel tanks and retaining wall; 2 story, 80 x 280 ft. warehouse and wharf at Beverly, Mass.

Refinery—T. L. Roway and E. L. Chapman, Big Springs, Tex., has work under way on the construction of a 20 x 75 ft. refinery to include four bubble towers, 8 condensers, pumping plant, office, etc. Estimated cost $200,000.

Refinery (Oil)—Canadian Oil Companies Ltd., 12 Strachan Ave., Toronto, Ont., plans addition to refinery and oil storage plant at Petrolia, Ont. Estimated cost $250,000. Private plans.

Refinery (Oil)—J. B. Nicholas, Chickasha, Okla., is having preliminary plans prepared for the construction of an oil refinery. Estimated cost $75,000. Private plans.

Refinery (Oil) — Standard Oil Co. of New Jersey, 26 Broadway, New York, is receiving bids for the construction of an oil refinery at Rouen, France. Estimated cost $8,000,000.

Refinery (Corn Products)—Corn Products Refining Co., 608 Brokers St., Kansas City, Mo., awarded contract for addition to plant to Bedford Construction Co., 260 East Illinois Ave., Chicago, Ill. Estimated cost $250,000.

Plant — Metal Process Co., Evansville, Ind., awarded contract for a factory to M. J. Hoffman Construction Co., 403 Furn. Bldg., Evansville. Estimated cost $250,000. Two overhead electric cranes and automatic blast furnaces will be required.

Refinery (Metal)—United States Metal Refining Co., Delamar Ave., Carteret, N. J., will build a 1 story refinery. Estimated cost $40,000. Private plans. Work will be done by separate contracts.

Refractories Plant — Corundite Refractories Inc., Massillon, O., awarded contract for a 1 story factory to house proposed new tunnel kiln to T. L. Pixon Co., Pittsburgh, Pa. Estimated cost $50,000.

Rubber Factory Addition—Ohio Rubber Co., Willoughby, O., awarded contract for a 1 story, 120 x 400 ft. addition to factory to George A. Rutherford Co., 2725 Prospect Ave., Cleveland. Estimated cost $200,000.

Rubber Products Manufacturing Plant—American Rubber Products Inc., Matson Bldg., San Francisco, Calif., awarded contract for a 1 story, 100 x 102 ft. rubber product manufacturing plant at Salinas to E. F. Reese, 158 Central Ave., Salinas. $150,000.

Smelter — International Nickel Co., Copper Cliff, Ont., awarded contract for remodeling and reconstructing old smelter into building to house refinery now at Port Colborne, to Fraser-Brace Engineering Co. Ltd., 107 Craig St. W., Montreal, Que. Estimated cost $2,000,000.

Smelter Plant — Texas Mining & Smeltering Co., H. P. Henderson, Pres., 522 5th Ave., New York, N. Y., awarded contract for the construction of a 110 x 140 ft. antimony smelter plant, at Laredo, Tex., to Alamo Iron Works, 130 Santa Clara St., San Antonio; steel to Truscon Steel Co., Builders Exchange Bldg., San Antonio. Estimated cost $150,000. Soon lets contract for equipment including pipe, ovens, etc.

Soap Warehouse—Los Angeles Soap Co., 717 East First St., Los Angeles, Calif., awarded contract for a 5 story, 50 x 100 ft. warehouse on Banning St. to Baruch Corp., Lincoln Bldg., Los Angeles.

Tannery—Frankling Tanning Co., C. A. Cross, Pres., Curwensville, Pa., awarded contract for foundation for a 2 story, 50 x 100 ft. tannery in Clearfield County to W. E. Miller, Glen Willard. Estimated cost $40,000.

INDUSTRIAL NOTES

Yeomans Brothers Company, Chicago, manufacturers of sewage and drainage pumping equipment, have appointed C. Calor Mota as exclusive representative of their products in Porto Rico. Mr. Calor's offices are located in Mayaguez, Porto Rico.

Foote Bros. Gear & Machine Company, 111 North Canal St., Chicago, Ill., has recently appointed J. L. Hart Machinery Co., South Florida and Eunice Aves., Tampa, Fla., representative of the company in the state of Florida, south of a line drawn east and west across the state from Centralia to Titusville.

The Fuller Company has opened an office at 1118 Marquette Building, Chicago. The sales engineer in charge of the sales office is J. M. Alonso.

Effective Aug. 1, 1930, A. F. Murphy was appointed works manager of the Zanesville division of the American Rolling Mill Company at Zanesville, Ohio. Zanesville will now be operated as a separate unit, one of Armco's four manufacturing divisions.

The Bailey Meter Company, Cleveland, manufacturer of power plant metering equipment, automatic combustion control, and feed water regulators, announcecs the opening of a branch office in Denver. M. E. Reddick has been appointed manager.

The Hull Company, 130 Clinton Street, Brooklyn, N. Y., has appointed the Chas. S. Tanner Company, of 244 South Water St., Providence, R. I., as its representatives for the New England territory.

The Foster Wheeler Corporation, New York City, announces the opening of another branch office, located at 712 Thompson Building, Tulsa, Okla., in charge of C. C. Steward.

The Horton Steel Works, Ltd., of Bridgeburg, Ontario, has acquired from the Canadian Barking Drum Company, Ltd., the rights to sell and service, as well as to manufacture, U-Bar barking drums and accessory equipment. Formerly, the Horton Steel Works, Ltd., handled only the fabrication of the equipment.

The Minneapolis-Honeywell Regulator Company announces the opening of a branch office at 218 East Washington St., Syracuse, N. Y., under the management of Kenneth Sprague; taking over the Minneapolis-Honeywell distributorship carried on for many years under the name of Kenneth Sprague's father, Frank Sprague.

The Quigley Furnace Specialties Company announces a change in the name of the company to Quigley Company, Inc., owing to the rapid and broad development of its products during the last few years.

On Sept. 1, Barrett-Cravens Company, manufacturer of Barrett lift-trucks, steeleg platforms and portable elevators, moved into its new modern plant at 101 West 87th Street, Chicago.

Effective Aug. 1, 1930 the Reynolite division of the Reynolds Spring Co., Jackson, Mich., became the wholly owned subsidiary of Cutler-Hammer, Inc.